Draft Engineering Evaluation/Cost Analysis
ROCK CREEK ABANDONED MINE SITES

Daniel Boone National Forest
Stearns Ranger District
McCreary County, Kentucky

Prepared For:

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ACRONYMS

°C	degrees Celsius
°F	degrees Fahrenheit
µS/cm	microsiemens per centimeter
Al	aluminum
ALD	Anoxic Limestone Drain
AMD	Acid Mine Drainage
AML	Abandoned Mine Lands
APA	Abbreviated Preliminary Assessment
APRSC	Annual Post-Removal Site Control
ARAR	Applicable or Relevant and Appropriate Requirement
BMP	Best Management Practice
BTU	British thermal unit
CAA	Clean Air Act
$CaCO_3$	calcium carbonate
CaO	calcium oxide
$Ca(OH)_2$	calcium hydroxide
CCI	Cost Construction Index
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
cfs	cubic feet per second
cm	centimeters
COC	Contaminants of Concern
COI	Contaminants of Interest
DAOS	Dosing with Alkali, Oxidation, and Sedimentation
DBNF	Daniel Boone National Forest
DO	dissolved oxygen
DOE	U.S. Department of Energy
EE/CA	Engineering Evaluation/Cost Analysis
EM	Environmental Management
EPA	U.S. Environmental Protection Agency

ESI	Expanded Site Inspection
Fe	iron
Fe^{2+}	ferrous iron
ft	feet
FY	Fiscal Year (US Government – October-September)
gpm	gallons per minute
ha	hectares
KAR	Kentucky Administrative Regulations
KDEP	Kentucky Department for Environmental Protection
km	kilometers
KYDAML	Kentucky Division of Abandoned Mine Lands
LB	Limestone Bed
LLB	Limestone Leach Bed
LSD	Limestone Sand Dumping
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
m	meters
mg/day	milligrams per day
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
mm	millimeters
msl	mean sea level
MVFP	Modified Vertical Flow Pond
Na_2CO_3	sodium carbonate
NaOH	sodium hydroxide
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NEPA	National Environmental Policy Act
NPL	National Priorities List
NRCS	Natural Resources and Conservation Service
O&M	Operations and Maintenance
OHV	Off-Highway Vehicle

OLC	Open or Oxic Limestone Channel
OSMRE	Office of Surface Mining and Reclamation
PA	Preliminary Assessment
PA/SI	Preliminary Assessment/Site Inspection
PPE	Probable Point of Entry
PRB	Permeable Reactive Barrier
PRG	Preliminary Remediation Goal
RAO	Removal Action Objective
RML	Removal Management Level
SACM	Superfund Accelerated Cleanup Model
SAPS	Successive Alkalinity Producing Systems
SARA	Superfund Amendments and Reauthorization Act
SI	Site Inspection
SMCRA	Surface Mining Control and Reclamation Act
SRB	Sulfate-Reducing Bioreactor/Bacteria
TBC	To Be Considered (guidance)
TMDL	Total Maximum Daily Load
TSS	Total Suspended Solids
TVA	Tennessee Valley Authority
URS	URS Group, Inc.
USDA	United States Department of Agriculture
USDA FS	United States Department of Agriculture Forest Service
USDI OSM	United States Department of Interior Office of Surface Mining
USEPA	United States Environmental Protection Agency

EXECUTIVE SUMMARY

URS Group, Inc. (URS) developed this Engineering Evaluation/Cost Analysis (EE/CA) for the United States Department of Agriculture Forest Service (USDA FS). This EE/CA presents an engineering evaluation and cost analysis of alternatives for response and restoration work proposed for contaminated mining-related discharges from ten (10) abandoned coal mine sites in the Rock Creek Watershed. The Rock Creek watershed is about 37,000 acres in size, of which 24,000 acres comprise federally-owned surface lands under National Forest System management. The upper (southern) one-half of Rock Creek, between the Tennessee-Kentucky border and the confluence of White Oak Creek with Rock Creek at White Oak Junction, has been relatively undisturbed by mining and yields high-quality water. This reach of the stream has been designated a State Wild River and supports a valuable trout fishery, which is maintained with a stocking program managed by the Kentucky Department of Fish and Wildlife Resources. East of the confluence with White Oak Creek, however, Rock Creek is on Kentucky's 303(d) list of impaired waters due to low pH and elevated metals. The Rock Creek watershed is a major recreational attraction and is visited by thousands yearly. Fishing, hunting, hiking, backpacking, and camping are just a few of the interests pursued by visitors.

Of these ten individual sites that comprise the Site, four occur at locations that drain either directly to White Oak Creek (Big Momma Mine and Cooperative South Mines) or via tributaries (Cabin Branch Mines and Jones Branch Mines) of White Oak Creek. One individual site/complex, Upper Rock Creek Fidelity North Mine is located on Rock Creek before it merges with White Oak Creek. The remaining five individual sites are located on tributaries of lower Rock Creek, downstream of the confluence of White Oak Creek and Rock Creek.

The purpose of this EE/CA is to provide a process and rationale for developing, screening, and evaluating potential removal actions designed to address mining-related impacts at the Rock Creek abandoned mine sites included in the EE/CA. The EE/CA process of evaluating potential removal actions concludes with recommendations for an appropriate response or removal action alternative for each site. The purpose of a removal action is to "abate, prevent, minimize, stabilize, mitigate or eliminate the release or the threat of a release" (Title 40 of the Code of Federal Regulations [40 CFR] 300.415). The EE/CA for a removal action is intended to:

- Satisfy environmental review requirements for removal actions;
- Satisfy administrative record requirements for documentation of removal action selection; and
- Provide a framework for evaluating and selecting alternative technologies.

This EE/CA was developed using the "non-time-critical removal" process outlined in the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended in 1986, and the updated National Oil and Hazardous Substances Pollution Contingency Plan (NCP). Following receipt of public comment on the preferred response action alternatives identified in this document, the USDA-FS will select applicable response alternatives by site in an Action Memorandum.

Drainage from abandoned coal mines typically contains high concentrations of sulfate and total dissolved solids. It is an often acidic, metals-bearing leachate, the specific characteristics of which can be highly variable depending upon the properties of the sulfide-bearing source materials and the contacting water and is commonly referred to as acid mine drainage (AMD). The drainage generally has low pH and elevated metal acidity, and commonly has elevated concentrations of iron, manganese, aluminum, and lead. In addition, the drainage typically has high suspended sediment concentrations as a result of ferric hydroxide precipitates and their associated slow settling velocity.

The AMD issues associated with each of the ten individual sites comprising the Site have been addressed to some extent by Preliminary Assessments (PAs), Site Inspections (SIs), or an Abbreviated Preliminary Assessment (APA) prepared for the sites, and by the application of various treatment technologies by the Kentucky Division of Abandoned Mine Lands (KYDAML). The APA and the PA/SIs have determined that sufficient potential for harm exists at the Site to necessitate a Removal Action and the associated EE/CA report. The results from previous sampling and analyses activities performed from 2002 through 2009 are briefly discussed in this EE/CA, along with supplemental sampling and analyses performed in 2014, to fill data gaps and enable the production of a more comprehensive EE/CA report.

Preliminary Assessments and Site Inspections: 2002 through 2009

In 2002 through 2004, the USDA FS performed a coal mine features and AMD seeps inventory within the DBNF, including the Rock Creek abandoned mine sites. Coal mine features included mine openings (adits, portals, and shafts), coal refuse (waste) piles, ground surface subsidence, equipment, and structures. The efforts included features characterization and preliminary sampling and chemical analysis of AMD (seeps and flows) and sedimentation ponds.

In 2004 through 2007, Big Momma Mine, Cabin Branch Mine, Grassy Fork Mine, Jones Branch Mine, Paint Cliff/Mine 16 Complex Mine, and Poplar Spring Hollow Mine were sampled again based on the results from the 2002 and 2004 sampling. In each instance, a CERCLA PA was first prepared by BAT Associates, Inc., which concluded that the possibility of a release of a hazardous substance or pollutant or contaminant existed for the surface water, groundwater, and soil pathways. The follow up CERCLA SIs confirmed in each instance the release of one or more hazardous substances, such as one or more heavy metals, including cadmium, lead and zinc, and the release of pollutants or contaminants including aluminum and iron, as well as elevated sulfate concentrations, together with the associated development of low pH levels in seep waters from portals and coal refuse piles.

In 2009, another sampling of Rock Creek and its relevant tributaries was conducted by Tennessee Valley Authority (TVA) personnel working on behalf of the USDA FS, primarily at strategic locations relative to drainage from mine areas. Data taken from these 2009 sampling analyses as well as the original coal mines features inventory were used by USDA FS to prepare an APA addressing releases of hazardous substances and pollutants or contaminants from Cooperative South Mine, Koger Fork Mine, Upper Rock Creek /Fidelity North Mine, and Water Tank Hollow Mine.

Interim Removal Actions: 2000 through 2003

In spring 2000, KYDAML implemented a pilot treatment/restoration project along the Lower Rock Creek watershed, which included White Oak Creek from Cabin Branch downstream to the confluence with Rock Creek at White Oak Junction, together with Rock Creek from White Oak Junction to the confluence with the Big South Fork. The project was located within Cabin Branch, Cooperative North Portal, and Jones Branch of White Oak Creek, and in Roberts Hollow, Paint Cliff, Poplar Spring Hollow, Koger Fork, and the mouth of Water Tank Hollow on Rock Creek.

Techniques used to accomplish reduction in acidity included monthly dumping of limestone sand, removal and treatment of acidic coal refuse from the banks of Rock Creek, installation of open limestone channels

(OLCs), and installation of a modified vertical flow system at Paint Cliff. Existing culvert outlets from the main tributaries into White Oak Creek and Rock Creek were used as limestone sand dumping sites. The pilot project continued with monthly dosing until the fall of 2001 when it ended due to low flow conditions.

After two months of dosing, water quality at the mouth of Rock Creek changed from net acidic to net alkaline. After four months of dosing, water quality at the mouth of White Oak Creek changed from net acidic to net alkaline.

Based on the positive results of the pilot project, the decision was made to build permanent dosing stations in the main tributaries and continue with monthly dosing. Monthly dosing resumed in late winter 2002 with the increase in base flow. The rate of dosing continued to be double the calculated rate for the first year, and was reduced to the calculated rate thereafter. Dosing at double the calculated rate for the first year resulted in the accumulation of one year's worth of neutralization potential in the streambed.

After two months of dosing, the net acid load from Rock Creek into the Big South Fork was reduced from a monthly average of 110 metric tons (121 US tons) per month before dosing to a monthly average of 0.063 metric tons (0.069 US tons) per month. After four months of dosing the net acid load entering Rock Creek from White Oak Creek, for the months having flow, was reduced from an average of 13 metric tons (14 US tons) per month before dosing to an average of 0.015 metric tons (0.017 US tons) per month.

The broad outcome of the abatement project was a major reduction of acid loading from White Oak Creek into Rock Creek and from Rock Creek into the Big South Fork of the Cumberland River in each instance after completion of the abatement project. While the abatement project addressed the reduction in releases of acidity, as well as iron and aluminum concentrations, effects on the levels of trace metals in the mine drainage and stream systems were not examined (Carew et al., 2005).

2014 Supplemental Site Investigations

Supplemental sampling and analyses were performed in 2014 to fill data gaps and the analytical results for surface water, refuse pile toe pore water (groundwater), and sediment samples were used to establish the nature and extent of AMD impact at each of the sites within the Rock Creek watershed. The results were compared to federal and State of Kentucky standards to identify contaminants of interest (COI) at each of the sites.

For surface water samples, the pH value was compared to the Kentucky Surface Water Standards for a warm water aquatic habitat, which require the pH to be between 6.0 and 9.0. The applicable criteria for silver, arsenic, cadmium, chromium, copper, iron (if aquatic life has been shown to be affected), mercury, nickel, lead, and selenium are from the Kentucky Surface Water Standards for a warm water aquatic habitat. Barium and sulfate values are compared to the Kentucky Surface Water Standards for a domestic water supply source. For conductivity, the sample value is compared to the USEPA's July 2011 Final Appalachian Mining Guidance, which requires the conductivity to be below 500 microsiemens per centimeter (µS/cm). The applicable criteria for aluminum, beryllium, antimony, and thallium are from the USEPA Region 4's Ecological Risk Assessment Fresh Water Surface Water Screening Values. Lastly, the upper threshold for manganese of 0.50 milligrams per liter (mg/L) is from the USEPA's National Secondary Drinking Water Regulations' Maximum Contaminant Levels (MCLs).

For the sediment samples, the USEPA Region 4 May 2014 Generic Removal Management Levels (RMLs) for Residential Soil were used as the applicable criteria for each analysis. For the pore-water samples, which for comparison purposes are categorized as groundwater samples, the analysis results for each sample were compared to the USEPA Secondary Drinking Water Standard, the MCL according to the USEPA National Primary Drinking Water Regulations, and the MCL Goal (MCLG), which designates the level of a contaminant in drinking water below which there is no known or expected risk to health.

Based on these analyses, metals and wet chemistry data exceeding the applicable standards in surface water include aluminum, beryllium, cadmium, chromium, copper, iron, manganese, nickel, zinc, conductivity, pH, and sulfate. Exceedances in one sediment sample collected from Big Momma include cobalt, iron, and manganese. Exceedances in pore water (groundwater) samples include aluminum, arsenic, iron, lead, manganese, thallium, pH, sulfate, and total dissolved solids. Site ranking of the Rock Creek abandoned mine sites was assessed based on acidity and metals loading. The purpose of the ranking was to prioritize the relative impacts associated with AMD at the ten sites and provide a mechanism for prioritizing removal actions with the high priority sites placed at the top. The ranking is as follows:

Based on Acidity Loading

1) Paint Cliff
2) Jones Branch
3) Big Momma
4) Cabin Branch
5) Cooperative South
6) Koger Fork
7) Roberts Hollow
8) Upper Rock Creek Fidelity North
9) Grassy Fork
10) Water Tank Hollow

Based on Metals Loading

1) Paint Cliff
2) Jones Branch
3) Big Momma
4) Cabin Branch
5) Koger Fork
6) Roberts Hollow
7) Cooperative South
8) Upper Rock Creek Fidelity North
9) Grassy Fork
10) Water Tank Hollow

Hazards that the contaminants from the Rock Creek abandoned mine sites present to the public health, welfare and the environment based on criteria established by federal regulations and USDA FS guidelines were identified. A conceptual site model based on the potential contaminant migration pathways was also developed. Streamlined human health and ecological risk assessments were evaluated to assess potential risks to human health and ecological receptors from exposure to coal waste, sediment, and surface water at the site. Analytical data and other information presented in the PA/SI reports and the 2014 sampling were evaluated based on risk-based cleanup criteria set by the state and/or federal regulations and guidelines. Contaminants exceeding these standards present ecological risks to aquatic life from ingestion and direct contact as well as humans. In addition, wildlife species may be at risk from these discharges, although a detailed exposure assessment and risk characterization was not performed.

Removal Action Alternatives

URS identified and evaluated numerous potential cleanup technologies in developing the EE/CA. Removal action technologies applicable to the sites were identified based on a review of technical literature and previous experience at similar mine sites. A set of potential removal action alternatives was initially screened using a predefined set of criteria consistent with USEPA guidance on conducting an EE/CA. The technologies were screened to eliminate inappropriate, ineffective, infeasible, or cost prohibitive methods. A smaller set of alternatives resulting from the initial screening was evaluated using professional engineering judgment based upon the criteria of effectiveness, implementability, cost, and compliance with site-specific

Applicable or Relevant and Appropriate Requirements (ARARs) to the extent practicable. This document includes a detailed evaluation of the following categories of technologies:

- Limestone-based systems (passive treatment technologies)
    - Modified Vertical flow ponds (MVFP)
    - Anoxic limestone drains (ALD)
    - Oxic limestone channels (OLC)
    - Limestone beds (LB)
    - Limestone sand dumping (LSD); and
- In-line active treatment of AMD flows
    - Chemical addition and precipitation
    - Permeable Reactive Barrier (PRB)

A few of the passive treatment systems can be reliably implemented as a single permanent solution for most AMD problems to meet ARARs limits; however, relative to active treatment, passive systems require longer retention times and greater space; provide less certain treatment efficiency; and are subject to failure in the long-term if not adequately maintained. Due to the extremely poor water quality at a few of the Rock Creek abandoned mine sites, these technologies may be installed in series to achieve the removal action objectives and/or serve as a polishing or finishing action to remove additional metals or to increase the alkalinity of the water leaving the site. The installation of a series or combination of treatment systems would allow continued operation during breakdown or maintenance, and adjustments or further testing in the case of some of the technologies that are not fully developed.

Active treatment is generally limited to at-source treatment systems and is largely based on industrial wastewater treatment technologies. Active treatment requires a supporting infrastructure, some form of power, and periodic routine maintenance. While active technologies can potentially be very effective at removing metals to the low aquatic standards, the remoteness of some of the sites and almost inaccessibility to the sites during winter suggests that the successful implementation of these technologies could be difficult and expensive.

Removal action alternatives identified for the Rock Creek abandoned mine sites include:

E1. **Alternative 1:** No Action Alternative (applicable to all the sites)

E2. Cabin Branch

- Alternative 2: 1st settling pond; MVFP; 2nd settling pond; and Pebble Quicklime dosing.
- Alternative 3: 1st settling pond; MVFP; and 2nd settling pond.

E3. Big Momma

- Alternative 2: ALD; MVFP; and settling pond.
- Alternative 3: 1st settling pond; MVFP; and 2nd settling pond.
- Alternative 4: MVFP; settling pond; LSD; and Caustic Soda dosing.

E4. Cooperative South

- Alternative 2: Oxic/OLC; settling pond; and LSD.
- Alternative 3: 1st LSD; settling pond; and LSD.

E5. Jones Branch:

- Alternative 2: 1st settling pond; MVFP; 2nd settling pond; and LSD.
- Alternative 3: ALD; MVFP; settling pond; LSD; and Pebble Quicklime dosing.

E6. Paint Cliff/Mine 16 Complex:

- Alternative 2: Settling pond; Pebble Quicklime dosing; and OLC.
- Alternative 3: 1st settling pond; 1st MVFP; 2nd MVFP; 2nd settling pond; and OLC.

E7. Roberts Hollow:

- Alternative 2: 1st settling pond; 1st MVFP; 2nd MVFP; 2nd settling pond; and LSD.
- Alternative 3: 1st settling pond; Pebble Quicklime dosing; 2nd settling pond; and LSD.

E8. Poplar Spring:

- Alternative 2: 1st settling pond; MVFP; LB; and 2nd settling pond.
- Alternative 3: 1st settling pond; MVFP; 2nd settling pond; LB; and OLC.

E9. Koger Fork:

- Alternative 2: Soil Cover BMP; Pebble Quicklime dosing; and OLC.
- Alternative 3: Soil Cover BMP; OLC; and LSD.

E10. Water Tank:

- Alternative 2: Soil Cover BMP; and PRB wall.
- Alternative 3: Soil Cover BMP; and LSD.

E11. Grassy Fork:

- Alternative 2: LSD
- Alternative 3: Pebble Quicklime dosing; and LSD

Based on a comparative analysis, the preferred alternative for each site consists of a combination of treatment options which will be protective of human health and the environment, can meet the action and location-specific ARARs, contribute toward meeting the chemical-specific ARARs, and meet the Remedial Action Objectives (RAOs). The preferred alternatives are effective in both the long term and short term, and would likely not be inconsistent with the long term remedy at each of the ten sites. Each recommended alternative is implementable from both a technical and administrative standpoint, and would be the most cost-effective alternative at reducing release of AMD impacts. The recommended alternatives for majority of the sites are a combination of limestone-based passive treatment technologies and, in a few instances, active treatment using either pebble quicklime or caustic soda. The recommended alternatives and estimated costs to implement and maintain consist of the following:

Cabin Branch

- Alternative 3: 1st settling pond; MVFP; and 2nd settling pond.

- Capital Cost: $287,814
  Annual Cost: $23,376

Big Momma

- Alternative 3: 1st settling pond; MVFP; and 2nd settling pond.

- Capital Cost: $392,271
  Annual Cost: $23,376

Cooperative South

- Alternative 2: OLC; Settling pond; and LSD.

- Capital Cost: $171,414
  Annual Cost: $18,496

Jones Branch:

- Alternative 2: 1st settling pond; 1st MVFP; 2nd MVFP; 2nd settling pond; and LSD.

- Capital Cost: $441,220
  Annual Cost: $23,376

Paint Cliff/Mine 16 Complex:

- Alternative 3: 1st settling pond; 1st MVFP; 2nd MVFP; 2nd settling pond; and OLC.

- Capital Cost: $555,182
  Annual Cost: $18,496

Roberts Hollow:

- Alternative 2: 1st settling pond; 1st MVFP; 2nd MVFP; 2nd settling pond; and LSD.

- Capital Cost: $463,998
  Annual Cost: $23,376

Poplar Spring:

- Alternative 3: 1st settling pond; MVFP; 2nd settling pond; LB; and OLC.

- Capital Cost: $334,781
  Annual Cost: $18,496

Koger Fork:

- Alternative 3: Soil Capping via BMP; OLC; and LSD.

- Capital Cost: $175,034
  Annual Cost: $13,616

Water Tank:

- Alternative 2: Soil capping via BMP; and PRB wall.

- Capital Cost: $348,408
  Annual Cost: $13,616

Grassy Fork:

- Alternative 2: LSD.

- Capital Cost: $94,185
  Annual Cost: $13,616

The total estimated removal action cost for the Rock Creek abandoned mine sites is $3,454,093 and the estimated average annual O&M cost is $18,984 per site including the periodic replacement of lime-based components. Long-term monitoring of water quality in White Oak Creek and Rock Creek that will be done as part of the overall project plan will allow the USDA FS to regularly evaluate whether these alternatives continue to be appropriate for the watershed.

1. INTRODUCTION

URS Group, Inc. (URS) developed this Engineering Evaluation/Cost Analysis (EE/CA) for the United States Department of Agriculture Forest Service (USDA FS). This EE/CA presents an engineering evaluation and cost analysis of alternatives for response and restoration work proposed for contaminated mining-related discharges from ten (10) abandoned coal mine sites in the Rock Creek Watershed (see **Figures 1** and **2**). The Rock Creek watershed is about 37,000 acres in size, of which 24,000 acres comprise federally-owned surface lands under National Forest System management. The upper (southern) one-half of Rock Creek, between the Tennessee-Kentucky border and the confluence of White Oak Creek with Rock Creek, has been relatively undisturbed by mining and yields high-quality water. This reach of the stream has been designated a State Wild River and supports a valuable trout fishery, which is maintained with a stocking program managed by the Kentucky Department of Fish and Wildlife Resources. East of the confluence with White Oak Creek, however, Rock Creek is on Kentucky's 2004 303(d) list of impaired waters due to low pH and elevated metals. The Rock Creek watershed is a major recreational attraction and is visited by thousands yearly. Fishing, hunting, hiking, backpacking, and camping are just a few of the interests pursued by visitors.

The Rock Creek abandoned coal mine sites (Site), as addressed in this EE/CA, is an aggregation of 10 previously-investigated sites/complexes occurring within the Rock Creek watershed. In **Figure 2**, the stars represent the approximate center point of the array of mines that comprise each complex. These 10 individual sites reflect, to varying extents, the effects of acid mine drainage (AMD) as a result of drainage from abandoned underground mining complexes. Mining features of concern include both open and collapsed underground mine portals and adits, as well as unlined pyritic coal waste/spoil piles (see **Figure 3**). Coal waste/spoil piles cover from 4 to 44 acres, and amounts range from minimal quantities to as much as one million tons of coal waste on individual sites. These inadequately reclaimed sites currently produce AMD that eventually enters the local tributaries/streams and ultimately into Rock Creek.

Drainage from these sources typically contains high concentrations of sulfate and total dissolved solids. It is an often acidic, metal-bearing leachate, the specific characteristics of which can be highly variable depending upon the properties of the sulfide-bearing source materials and the contacting water. The drainage generally has low pH and elevated metal acidity, and commonly has elevated concentrations of iron, manganese, aluminum, and lead. In addition, the drainage typically has high suspended sediment concentrations as a result of ferric hydroxide precipitates and their associated slow settling velocity.

The AMD issues associated with each of the 10 individual sites comprising the Site have been addressed to some extent by Preliminary Assessments (PAs), PA/Site Inspections (SIs), or an Abbreviated Preliminary Assessment (APA) prepared for the sites, and by the application of various treatment technologies by the Kentucky Division of Abandoned Mine Lands (KYDAML). The APA and the PA/SIs have determined that sufficient potential for harm exists at the Site to necessitate a Removal Action and the associated EE/CA report. The results from previous sampling and analyses activities performed from 2002 through 2009 are briefly discussed in this EE/CA, along with supplemental sampling and analyses performed in 2014, to fill data gaps and enable the production of a more comprehensive EE/CA report. In this report, identified impacts related to these discharges are described and characterized, response alternatives are proposed, and the costs of implementing an alternative are estimated.

The primary sources of data used to evaluate Site conditions, and to develop removal action alternatives, are the PA/SI reports prepared by BAT Associates, Inc. (BAT) (BAT 2009 and 2010), the APA report prepared by the USDA FS (Davis 2013), and Supplemental Sampling performed by the USDA FS from May through July 2014.

The purpose of this EE/CA is to provide a process and rationale for developing, screening, and evaluating potential removal actions designed to address mining-related impacts at the Rock Creek abandoned mine sites included in the EE/CA. The purpose of a removal action is to "abate, prevent, minimize, stabilize, mitigate or eliminate the release or the threat of a release" (Title 40 of the Code of Federal Regulations [40 CFR] 300.415). The EE/CA for a removal action is intended to:

- Satisfy environmental review requirements for removal actions;
- Satisfy administrative record requirements for documentation of removal action selection; and
- Provide a framework for evaluating and selecting alternative technologies.

To meet these purposes, this EE/CA identifies objectives for the removal action and evaluates the effectiveness, implementability, and cost of various alternatives that may satisfy these objectives.

1.1. Statutory Framework

This EE/CA has been prepared in accordance with the Non-Time-Critical Removal Action process described in the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). Non-time-critical removal actions represent a primary tool in the Superfund Accelerated Cleanup Model (SACM), which has been developed by the U.S. Environmental Protection Agency (EPA) to allow site cleanups to proceed in a more timely and efficient manner, while achieving prompt risk reduction through a continuous process of assessing site conditions and the need for removal actions (EPA 1993). Although the Rock Creek abandoned mine sites are not federal National Priorities List sites, the EE/CA process is being invoked for possible removal actions on USDA FS lands through the USDA FS's CERCLA authority.

CERCLA and the NCP define removal actions to include "the cleanup or removal of released hazardous substances from the environment; such actions as may necessarily be taken in the event of the threat of release of hazardous substances into the environment, such actions as may be necessary to monitor, assess, and evaluate the release or the threat of release of hazardous substances, the disposal of removed material, or the taking of such other actions as may be necessary to prevent, minimize, or mitigate damage to the public health or welfare or to the environment, which may otherwise result from a release or threat of release" (EPA 1993). Non-time-critical removal actions refer to actions where implementation is not required within six months.

1.2. Report Organization

Section 2 of this document presents a site description of the Rock Creek abandoned mines in terms of site location, climate, geology and hydrogeology, surface water hydrology, mining history, and background. **Section 3** describes the previous investigations and removal actions. **Section 4** presents site characterization data used to finalize the source, nature, and extent of AMD contamination. Data from the 2014 site investigation performed for this EE/CA supplemented previous data compiled to define the extent of mining-related impacts. **Section 5** presents cleanup criteria including Applicable or Relevant and Appropriate Requirement (ARAR)-based concentrations in surface water, Kentucky and United States Environmental Protection Agency (USEPA) Region IV Standards, and preliminary risk-based cleanup concentrations. **Section 6** presents the removal action objectives and schedules.

Section 7 includes identification and analysis of management and removal action alternatives for adit-openings, refuse piles, and AMD/surface water. **Section 8** includes a comparative analysis of the removal action alternatives, with each alternative evaluated for effectiveness, implementability, and cost. **Section 9** presents the recommended removal action alternatives. **Section 10** includes a list of references cited in this document. The majority of figures and tables are included at the end of the report. Supplemental information is included as appendices.

Numerous other reports have been prepared for the Rock Creek abandoned mine sites over the years, including PA/SI reports completed by BAT Associates, Inc., an APA report completed by the USDA FS, and previous construction and reclamation reports (see **Section 10, References**). The reader is referred to these existing reports for additional information on the Rock Creek abandoned mine sites' characteristics, extent of mining-related impacts, and previous removal actions/reclamation activities completed at the sites.

2. SITE DESCRIPTION

2.1. Site Location

Rock Creek originates in Tennessee, flows just over 21 miles through McCreary County, Kentucky, first generally northward to its confluence with White Oak Creek, and then eastward discharging eventually into the Big South Fork of the Cumberland River (Big South Fork). The upstream (southern) portion of Rock Creek, between the Tennessee - Kentucky border and the confluence of Rock Creek with White Oak Creek, is largely undisturbed by mining and supports a high-quality trout fishery under the management of the Kentucky Department of Fish and Wildlife Resources in the past. This reach of Rock Creek (Upper Rock Creek) has been designated as a State Wild River. In contrast, the adjacent area for the northern portion of Rock Creek, downstream of the confluence with White Oak Creek (Lower Rock Creek), has been extensively mined for coal and is considered impaired due to low pH and elevated concentrations of some metals. This section of Rock Creek was originally listed on the Kentucky 303(d) List of Waters, which lists the streams and lakes that have been identified as not meeting one or more water quality standards, in 1998. Unfortunately, in 2010, river miles 16.5 to 21.5 of the previously clean portion of Rock Creek joined the adjacent area's listing on the Kentucky 303(d) List of Waters due to mercury in fish. The Kentucky Division of Water listed the Lower Rock Creek as a high priority nonpoint source-impacted stream due to low pH from AMD from numerous abandoned mine workings and coal refuse piles. These impacts are from mining activities that took place prior to the Surface Mining Control and Reclamation Act of 1977. The most recent 303(d) List of Waters includes Rock Creek miles 0.0 to 4.3, Rock Creek miles 16.5 to 21.5, and White Oak Creek miles 0.0 to 4.2 as Category 5 streams, which indicates that they are in need of a Total Maximum Daily Load (TMDL). Rock Creek flows mostly within lands managed by the Daniel Boone National Forest (DBNF), Stearns Ranger District.

Of these 10 individual sites that comprise the site, four occur at locations that drain either directly to White Oak Creek (Big Momma Mine and Cooperative South Mines) or via tributaries (Cabin Branch Mines and Jones Branch Mines) of White Oak Creek. One individual site/complex, Upper Rock Creek Mines, is located on Rock Creek before it merges with White Oak Creek. The remaining five individual sites are located on tributaries of Lower Rock Creek, downstream of the confluence of White Oak Creek and Upper Rock Creek.

2.2. Climate

Located within the southeastern interior portion of North America, Kentucky has a climate that can best be described as a humid subtropical climate. Temperatures in Kentucky usually range from daytime summer highs of around 87 degrees Fahrenheit (°F) (31 degrees Celsius [°C]) to the winter lows of around 23°F (-5°C). The average precipitation is 46 inches (1,200 millimeters [mm]) a year. Kentucky experiences four distinct seasons, with substantial variations in the severity of summer and winter.

The average daily high temperature for July increases from about 86°F (30 degrees °C) in the east to 90°F (32 degrees °C) in the west. High temperatures exceed 90°F (32 degrees °C) an average of 20 days per year in the north and east and 40 or more days in the south and west. Temperatures occasionally exceed 100°F (38 degrees °C). In January, average daily high temperatures increase from 38°F (3 degrees °C) in the north to 44°F (6.5 degrees °C) in the south. Cloudy skies are more frequent in winter, as most areas receive nearly 40 percent of available sunshine.

Average annual precipitation ranges from 42 inches in the north to 52 inches in the south. Much of the range is due to a strong precipitation gradient during the winter season. Summer precipitation patterns are less pronounced. Fall is normally Kentucky's dry season, while the spring season is typically the wettest, but precipitation is well distributed throughout the year. Snowfall is most likely from December to March, but it occasionally occurs as early as October or as late as April. Seasonal amounts average from nearly 10 inches in the south to more than 20 inches in the north. Across southern Kentucky, seasonal totals of less than 5 inches are fairly common, while totals of more than 20 inches are infrequent. Northern areas rarely receive less than 10 inches of snow and occasionally receive as much as 40 inches or more. Snow cover seldom persists for more than a week in the south or more than two weeks in the north.

2.3. Site Geology and Hydrology

The project area is located near the Cumberland, or Pottsville, Escarpment on the edge of the northern portion of the Cumberland Plateau, also referred to as the Eastern Kentucky Coal Fields. This plateau was formed by the resistant sandstones of the Pennsylvanian Age. The topography is highly dissected with steep stream valleys having elevations ranging from 1400 feet (427 meters [m]) above mean sea level on top of Rattlesnake Ridge to 740 feet (225 m) above sea level at the mouth of Water Tank Hollow. Stratigraphy of the Site includes the Lower Pennsylvanian Lee Formation on the upper slopes underlain by the Upper Mississippian Paragon Formation, which crops out on the lower slopes of the study area. The Mississippian sandstones and siltstones are the result of a great influx of mud, silts, and sands brought in by rivers and streams from uplands many miles to the northeast and deposited as a great delta.

The warm climate of the Pennsylvanian age grew extensive forests and great coastal swamps at the edges of water bodies. Marine waters advanced and receded many times, producing many layers of sandstone, shale, and coal. Vegetation of all types fell into the water and was buried under blankets of sediments, which over geologic time was compressed into coal. The non-vegetative sediments, such as sand, clay, and silt, were compressed into sandstone and shale. Over the last one million years, unconsolidated Quaternary sediments have been deposited along the larger streams and rivers. Quaternary alluvium is found on the banks and underlying Rock Creek at several locations including the Water Tank Hollow refuse site. The Rockcastle Conglomerate Member of the Lee Formation forms conspicuous cliffs near the top of the ridges in the study area.

The Beattyville Shale Member of the Lee Formation, located below the Rockcastle Conglomerate Member, consists of shale, siltstone, coal, and clay. The Stearns coal zone is located in the lower part of the Beattyville Shale Member. The coal beds in the Stearns coal zone are known locally as the Stearns Number (#) 1, # 1 ½, # 2, and # 3, and are commonly separated by only a few feet of sandstone, siltstone, or shale. Locally the coal beds may merge into one or two beds, or split into several very thin seams. Coal from the #1 seam has the best heating properties and the lowest sulfur content. This coal is topped by sandstone. The # 1 ½ seam is similar to #1, but is not as extensive. The # 2 seam has very high sulfur content and has historically produced AMD on a persistent basis. Hard pockets of sulfurous material are found in the upper margin of this seam, which is topped by soft carboniferous shale. This coal has variable chemistry, but pyrite-enriched zones (containing high amounts of sulfur) appear common in localized deposits and, where influenced by groundwater, produce very acidic flows with heavy metal content. When used as a fuel source for coal-fired power generating facilities, the resulting sulfur dioxide emissions, if unscrubbed, tend to exceed regulatory standards set by the Clean Air Act. These problems forced the mining industry to suspend mining of this coal.

The Paragon Formation consists of shale, sandstone, and limestone. The Water Tank Hollow refuse is located on the Paragon Formation and on alluvium on the north bank of Rock Creek. The majority of the Roberts Hollow refuse is located on Paragon Formation strata with the upper slope of the refuse located on the Beattyville Shale Member below the Stearns coal zone. The regional dip is to the east-southeast.

Five aquifer types have been identified within or near the project area including a karst aquifer flow regime and coal bed aquifers. In addition, groundwater flow in the study area is controlled by granular aquifers within the sandstone units, alluvial aquifers composed of unconsolidated sediments located along Rock Creek, and near surface fracture aquifers formed by stress relief fractures and joints, which may cut through and influence the other aquifer types. Recharge to the hillside aquifers occurs when precipitation soaks through the thin soils and colluvium, percolating down through the fractured units until a confining bed is reached. The groundwater then flows horizontally along bedding planes toward the hillside until the perched water is intercepted by vertical fractures in the confining bed or, in the absence of vertical fractures in the confining bed, is forced to the surface as wet weather springs. This results in a stair step pattern of groundwater movement from the ridge-tops to the valley floor.

Most groundwater used for domestic supply in this region of Kentucky is drawn from relatively shallow wells (less than 150 feet in depth) set in fractured bedrock or unconsolidated materials. The bedrock may be shale, sandstone, siltstone, limestone, or coal. Water can be stored in all these formations, but rapid movement of water is primarily controlled by secondary fractures – joints or faults that penetrate the rock near the land surface.

2.4. Surface Water Hydrology

Rock Creek flows in a northeasterly direction from its source in Tennessee into Kentucky (**Figure 3**) and then 21 miles (34 kilometers [km]) to its confluence with the Big South Fork of the Cumberland River at 36º43’01” latitude and -84º32’36” longitude. White Oak Creek is a 4800-acre (1940-hectares [ha]) watershed flowing in an easterly direction to its confluence with Rock Creek at White Oak Junction at 36º42’09” latitude and -84º35’47” longitude. Rock Creek catchment drains an area of approximately 63 square miles of predominantly steep terrain with dense forests. The abandoned coal mine sites lie within a well-dissected upland with a hilly to mountainous terrain. Cliff-lined gorges and resistant rock formations have produced many scenic features such as chimney rocks, natural arches, and waterfalls. Ridge top elevations of 1200 to 1500 feet prevail in the area with scattered ridges and knobs rising 600 feet or more above the general plateau level.

Rock Creek’s main stem is approximately 35.7 miles long (including the upper section in Tennessee) and drains an area of 40,109 acres (62.67 sq. miles). The average gradient is 23 feet per mile. Elevations for Rock Creek range from 1600 feet (ft.) above mean sea level (msl) in the headwaters to 775 ft. above msl at the mouth. White Oak Creek is a tributary to Rock Creek. Rock Creek is a perennial, swift-flowing mountain stream with spring flow rates of approximately 43 cubic feet per second (cfs) near the confluence with White Oak Creek, increasing to flows of 52 cfs at a point just 0.5 river miles before its entry into Big South Fork of the Cumberland River. The Big South Fork flows northeasterly across the eastern portions of the Cumberland Plateau.

Surface water flow paths in such steep terrain move quickly to small rivulets or streams that feed either Cabin Branch, Jones Branch, White Oak Creek, or Rock Creek itself. Drainage produced as leachate from coal refuse piles from each source area is, therefore, only minutes away from probable point of entry (PPE) into the nearest 2nd order stream channel. Rock Creek is a 3rd order effluent stream, receiving water from groundwater recharge during dry periods. The stream channel is, in large part, a bedrock-controlled channel whose form is predominantly shaped by the local geology and only slightly by stream flow. Under normal circumstances, the stream does not degrade very quickly and aggrades with sediment buildup only for short periods of time. The banks tend to be vertical with undercuts in some areas.

2.5. Mining History

The Stearns Coal and Lumber Company or its predecessors (Stearns) began purchasing land in Kentucky in approximately 1901 for the purposes of coal mining. Several coal seams were mined by underground mining methods: Stearns No. 1 seam, Stearns No. 1½ seam, Stearns No. 2 seam, and Stearns No. 3 seam. In 1937, Stearns sold approximately 46,800 acres to the United States for inclusion into the Daniel Boone National Forest (DBNF), while reserving the mineral rights associated with this acreage. This acquisition resulted in a split estate where the federal government owns and manages the surface estate and Stearns owned and managed the mineral estate, specifically coal and a very limited amount of oil and gas. Active mining continued into the mid-1970s. The mining resulted in large coal waste piles (commonly called refuse, slag, or slate). The waste materials from these mines were generally deposited in uncontrolled dumps near the mine openings.

A consent decree that transfers the minerals owned by Stearns to the United States was finalized and signed in 2011. This consent decree constitutes a settlement in lieu of payment by Stearns to reimburse the United States for response costs incurred or that will be incurred by the USDA FS for actions taken or to be taken in order to remediate environmental damage caused by coal mining activities in the Rock Creek watershed. On these acquired lands, a number of coal mines were inadequately reclaimed after closure, including three underground mines (#22, #24, and #25) that were opened in the mid-1960s and closed by late 1969. Other underground mines included Mine 16 complex, Mine Numbers 23, 21, 4, 11 and 18, Co-op North Mine, Co-op (Hickory Knob) Mine, Fidelity North Mine, Paint Creek Mines, Comargo Mine and Grassy Fork Mine These sites were characterized in general by both open and collapsed underground mine portals, large acid-/toxic-forming mine waste piles, landslides, and AMD. In the 1960s, a number of large fish kills were documented as being attributed to AMD, both within the Rock Creek watershed and in other watersheds with similar geology and mining history.

Several small towns were built supporting the mining and lumber industries of the area. Several of the towns including Yamacraw, Fidelity, and Co-Operative no longer exist. With the exception of a few small private in-holdings, the USDA FS manages most of the area encompassing the Rock Creek abandoned mine sites.

The National Park Service manages Rock Creek at its confluence with the Big South Fork of the Cumberland River as part of the Big South Fork National River and Recreation Area.

2.6. Rock Creek Abandoned Mine Sites Background – from the headwaters to the mouth

2.6.1 Cabin Branch and Unnamed Branch Mines

The Cabin Branch abandoned coal mine complex and coal waste pile sites are located in McCreary County on State Highway 1363 about ten miles west of Stearns, Kentucky in the Cumberland River watershed of the Daniel Boone National Forest (Stearns Ranger District), Kentucky (see **Figure 2**). The source area has an approximate center point at N 36° 41’ 70.0” and W 84° 37’ 38.0”. Mine #22 was operating in Cabin Branch in the #2 seam. The abandoned mine site is located above the confluence, at White Oak Junction, of Cabin Branch and White Oak Creek. Waste piles in the Cabin Branch area encompass about 7.3 acres at three different sites (see **Figure 3**). The affected area is approximately 459 acres. Three underground mines were opened in the mid-1960s and all were closed by late 1969. A considerable amount of hazardous substances can be found around the drift mine openings and slopes below. All the portals have caved in or have been permanently closed (using USDA FS AML safety funding), and AMD is draining from these collapsed portals.

Cabin Branch, a 2nd order effluent stream of Rock Creek, is recharged primarily from groundwater, not surface water, during the dry periods. The stream channel is, in large part, a bedrock-controlled channel whose form is predominantly shaped by the local geology and only slightly by stream flow. Under normal circumstances, the stream does not degrade very quickly and aggrades with sediment buildup only for short periods of time. The banks tend to be vertical with undercuts in some areas. Cabin Branch flows into White Oak Creek, which in turn flows into Rock Creek.

The unnamed tributary of White Oak Creek located immediately downstream from Cabin Branch (**Figure 4**) is identified in this report as Unnamed Branch, has a 220-acre (90-ha) watershed and flows in a southeasterly direction to its confluence with White Oak Creek.

In the late 1980s, Kentucky’s Division of Abandoned Mine Lands, in cooperation with the United States Department of Interior – Office of Surface Mining (USDI OSM), conducted an inventory of mining operations/disturbances in Rock Creek. As a result of this inventory, the Division elected to combine AMD sources in Cabin Branch with those in the Unnamed Branch watershed to the east of Cabin Branch as one unit (subsequently shown on their watershed map). The decision was based on the fact that coal from beneath the ridge system dividing these two sub-watersheds was removed from adits on the east side of Cabin Branch (i.e., Mine #25 that closed in November 1969), as well as from mine openings located on the west side of the Unnamed Branch watershed, indicating potential connectivity. In addition, given the fact that the regional structural dip is to the southeast, mine water would likely flow downgradient to the adjacent watershed to the east, the Unnamed Branch.

The Unnamed Branch has a coal refuse site located on the east side of the tributary. The Unnamed Branch receives discharges from several coal mine portals located within the watershed. In addition, there are several seeps flowing from the coal processing refuse and coal seams.

2.6.2 Big Momma Mine

Big Momma Mine is located on White Oak Creek within the Rock Creek watershed. The mine source area is located off State Highway 1363 approximately one mile west of the Big South Fork, which is one of the areas in the Commonwealth of Kentucky most heavily impacted by AMD (**Figure 5**). The site contains seep outfalls from underground mines. These seeps drain down a steep grade north of Highway 1363 and discharge into White Oak Creek, which empties into Rock Creek. The waste source area encompasses approximately 4.03 acres. Notably, the source area does not include any exposed coal refuse piles; however, most of the coal mined in the Big Momma Mine source area was in the Co-op North Mine and from the low grade #2 seam, which has a very high sulfur content.

2.6.3 Cooperative South Mine

Stearns is known to have mined the Stearns No. 1, Stearns No. 1 ½, and Stearns No. 2 coal seams. Additionally, maps from Stearns indicate that the Stearns No. 3 coal seam was mined in the Cooperative area from the Co-op (Hickory Knob) Mine. Cooperative South is the location where there are numerous large hills of coal refuse covering approximately 10 acres. These hills are now covered with trees so it is difficult to see that they are primarily comprised of coal refuse. Previous sampling of the refuse showed it contains significant British thermal unit (BTU) value (5,000 to 10,000 BTU). Site assessments have documented numerous "mountains" of coal waste, or refuse at Cooperative South. Seepage from these coal waste piles commonly transports hazardous substances to receiving streams. It is estimated that at least 1,000,000 tons of coal refuse are located at this site. The Cooperative North Portals discharge and flow into the north bank of White Oak Creek (**Figure 6**).

2.6.4 Jones Branch Mine

Jones Branch Mine is located in the upper reaches of Jones Branch (**Figure 7**). The Jones Branch Mine Site has several mine portals discharging AMD into the stream. Upper Jones Branch is lined on both sides with acidic mine refuse. The Jones Branch Mine Site includes mine seeps and waste materials from mining operations that were deposited in uncontrolled dumps near the mines. Extensive mining operations occurred in the 1940s at two sites, with Stearns #2 coal removed in the 225-acre upper mine. Stearns Co., Ltd. mining maps show that the Stearns #2 could have been mined from the Co-op Dobbs Mine. Little is known about the 15 acres of coal waste found at the lower mine further down the watershed. However, the mining maps show that Co-op North Mine with the Stearns #1 seam was likely mined in this Jones Branch lower watershed area. Mine waste was reportedly also transported underground from Roberts Hollow and dumped at this site in the late 1940s and early 1950s. Later, more waste was hauled in by truck. Some of the waste was subsequently burned, producing a quantity of usable coal refuse material (red dog), but most of it has a high potential acidity and is laden with impurities potentially damaging to water quality.

The Site contains three source areas that include several coal refuse piles and encompass a combined area of approximately 14.7 acres that affect a watershed area of 803 acres. These unlined coal refuse piles at the Jones Branch Mine Site have developed a vegetative cover, and many have been sloped to provide for increased drainage off the top of the piles. Approximately 803 acres have been affected by the AMD from the abandoned mines. The USDA FS implemented a watershed study at this site in 1959, with projects following in the early 1960s. Partial success was achieved with the establishment of some tree plantings on the waste dumps; however, no improvement of water quality was achieved in Jones Branch.

Two sinks have been observed in the stream bed of the Jones Branch tributary of White Oak Creek. The upper sink discharges at a spring located south of Highway 1363 opposite the church driveway located near the mouth of Jones Branch. The spring is about 10 feet (3 m) below the road elevation. The spring discharges into Rock Creek below White Oak Junction. During low flow, all of the water in Jones Branch sinks and discharges from this spring directly into Rock Creek bypassing White Oak Creek (see **Figure 8**). The lower sink in Jones Branch, which is located about 50 feet (15 m) upstream from the confluence of Jones Branch and White Oak Creek, has not been dye traced.

2.6.5 Upper Rock Creek Fidelity North Mine

Several pick and shovel mines in the No.1 seam near Fidelity, a community that once housed several hundred people, are producing small amounts of acid. Practically all trace of the community disappeared after mining stopped at the site in late 1930s. An old mine opening is located approximately 0.8 miles upstream from the road (see **Figures 8** and **9**). The Fidelity North Mine underlies this same area where the Stearns #1 seam was mined. Previous sampling results indicate that the surface water is being impacted by AMD containing elevated levels of toxic metals; however, due to minimal assessment work completed, only a few coal mine portals and coal waste piles have been identified in the area. It is also important to note that this section of Rock Creek is part of the State-designated Wild River and is considered an Outstanding State Resource Water.

2.6.6 Paint Cliff Mine and Roberts Hollow Mine

The Paint Cliff/Mine 16 Complex is located on State Highway 1363 about 10 miles west of Stearns, Kentucky (**Figure 10**). The site comprises of two sites in Roberts Hollow and two along Rock Creek. The Paint Creek Mines Company was active in the area mining the #2 seam between Roberts Hollow and Koger Fork during World War I. Following these years, the Stearns Coal and Lumber Company operated the mines until 1950. Later, Stearns leased their coal to B.R. Campbell and Son who opened Mine #16-2 at the mouth of Roberts Hollow and mined at this location until 1966. About two million tons of coal were produced from Mines #16 and #16-2 between 1948 and 1966. Most of the coal that was mined in the Paint Cliff/Mine 16 Complex was from deep mine #23, which supplied the #2 seam coal. Access to the mine was provided by a haul road that was constructed along the K & T Railroad right-of-way. The upper end of this road is now closed due to a past slope failure. As a byproduct of this production, over 400,000 tons of mine waste were generated. The Paint Cliff drainage is located between Roberts Hollow and Poplar Spring Hollow. The drainage discharges flow into the north bank of Rock Creek.

The Roberts Hollow site (**Figure 11**) has mine portals located above a 40-acre acidic coal refuse repository. In 2000, approximately 25,000 cubic yards of highly acidic coal refuse was relocated from the banks of Rock Creek at Water Tank Hollow and from the Paint Cliff coal load out site to an existing refuse area in Roberts Hollow. A 40-acre repository was constructed with agricultural limestone-filled foundation benches, a mixing of limestone with the refuse at a specified rate, the addition of a two-foot thick soil cover, and a final seeding of grasses, legumes, and trees. Unfortunately, both the mine portals and the refuse are continuing to contribute significant acid loading to Rock Creek. The Roberts Hollow watershed area is about 450 acres

(180 ha), 95% of which is federally-owned and administered by the USDA FS. Mine #16-2, formerly operated by B.R. Campbell & Son, is located near the mouth of the Hollow and coal was transported by rail. The Roberts Hollow refuse repository is located on the east side of the tributary. Roberts Hollow receives discharges from several coal mine portals located within the watershed. In addition, there are several seeps flowing from the coal processing refuse and coal seams. Roberts Hollow is a 420-acre (170-ha) watershed. An unnamed tributary at Roberts Hollow receives drainage from the 40-acre repository and flows in a southeasterly direction to its confluence with Rock Creek.

Four coal refuse piles and the repository at both the Paint Cliff and Roberts Hollow sites cover a combined total of about 54.1 acres and an affected area of approximately 344 acres. During the operation of the Paint Cliff mine, two to three acres of waste material were piled across the drainage leading to Rock Creek. Refuse pile A covers approximately one acre, refuse pile B approximately 10 acres, refuse pile C (or repository) approximately 40 acres, refuse pile D approximately one acre, and refuse pile E approximately two acres (Figure 3). These refuse piles were unlined, and have been sloped to provide increased drainage off the top of the piles. In addition, most of the piles have developed a vegetative cover.

2.6.7 Poplar Spring Hollow Mine

The Poplar Spring Hollow Mine Site is located on State Highway 1363 about 10 miles west of Stearns, Kentucky (**Figure 12**). This coal mine was opened in October 1965 in the No. 2 seam on the north side of Poplar Hollow and above the former K & T Railroad and near the confluence of Poplar Spring Hollow and Rock Creek. Deep mine #23, which supplied the #2 seam coal, was located in the headwaters of Poplar Spring Hollow. Poplar Spring Hollow receives discharges from several coal mine portals located within the watershed. In addition, there are several seeps flowing from the coal seam outcrop. In front of the mine portal, there is a pool of mine effluent that seeps into a drainage channel and flows down the steep slope towards Rock Creek, coating it with “yellow boy” iron precipitate. A number of dead and dying trees have been observed along the path of this mine drainage.

The waste spoils at this site cover about 4.3 acres and approximately 138 acres has been affected. This refuse pile is unlined, and has been sloped to provide for increased drainage off the top of the pile. The steep slope below the mine was badly damaged. Recently, remediation at this site has occurred through the efforts of a multi-agency task force. Access to the mine was provided by a haul road that was constructed along the former K & T Railroad right-of-way. The upper end of this road is now closed due to a past slope failure. Poplar Spring Hollow drainage flows in a southeasterly direction to its confluence with Rock Creek.

2.6.8 Koger Fork Mine

Koger Fork is an 800-acre (325-ha) watershed flowing into Rock Creek (**Figure 13**). The Stearns Co., Ltd. mining maps show that the Comargo Mine (# 1 seam), Mine Numbers 4 and 11 (# 1 ½ seam) and Mine Number 21 (# 2 seam) could have been mined in the Koger Fork area. A 10-acre Koger Fork coal processing refuse repository is located on a ridge between the left and right forks of the tributary. Sample results for Koger Fork indicate that the watershed is being impacted by AMD from abandoned coal mine features, including the 10-acre coal waste repository in the headwaters, numerous mine seeps along Koger Fork and its tributaries, and several large mine openings. The State of Kentucky performed limestone sand dumping further downstream in Koger Fork in the past in an effort to perform limited stream reclamation prior to its convergence with Rock Creek. Koger Fork flows in a northeasterly direction to its confluence with Rock Creek.

2.6.9 Water Tank Hollow Mine

The Water Tank Hollow site was a 3-acre coal processing refuse disposal site on the north bank of Rock Creek (**Figure 14**). The site lies adjacent to the former K & T Railroad, and the waste was reportedly dumped in the area. The original dump lies adjacent to Rock Creek and, over the years, large quantities of waste material have been pushed into the creek. An effort was made in 2000 by the State of Kentucky and the USDA FS to remove this material from Rock Creek. After removal of much of the refuse from the Water Tank Hollow and Paint Cliff sites, the slopes were graded to a smooth uniform configuration. At the Water Tank Hollow site, acid seeps were encountered near the toe of the slope during excavation of the coal mine refuse from the banks of Rock Creek. Several seeps have been observed flowing from the remaining refuse, one of which is flowing into the Water Tank Hollow tributary near the confluence with Rock Creek.

2.6.10 Grassy Fork Mine

The Grassy Fork Mines area is located off State Highway 1363 approximately one mile west of the Big South Fork (**Figure 15**). The site contains at least 13 mine portals that are located along Grassy Fork, a stream that discharges into Rock Creek. Along the stream is section 35 of the Sheltowee Trace National Recreation Trail. Waste piles in the Grassy Fork area encompass about 4.6 acres including a considerable amount of coal refuse around the mine openings and along the slopes and stream banks of Grassy Fork. In the early to mid-1900s, mines began operating in the Rock Creek watershed, including the site known as the Grassy Fork Mines complex. The Stearns Co., Ltd. mining maps show that Mines No. 4 and 11 (No. 1 ½ seam) and Mine 18 (No. 2 seam) may have been mined in the Grassy Fork area. Most of the coal mined in the Grassy Fork source area was, however, from the low grade #2 seam, which has a very high sulfur content.

There are more than 800 acres in the Grassy Fork Watershed. About 98 percent of this area is owned and managed by the USDA FS. The entire length of the road up to the last mine has been surfaced with coal mine waste. The same waste was used on the road at stream crossings and has been washed away, leaving raw banks.

During 1965, additional work was done in Grassy Fork near one of the old openings in the No. 1 ½ seam to gain entrance to the coal left from the first mining operation many years ago. The surface water flowing in the steep terrain of the Grassy Fork Mines area moves quickly as small rivulets or streams that feed directly into Grassy Fork. Low pH, contaminated drainage from coal refuse piles and mine portals are therefore, only minutes away from the PPE into Grassy Fork.

3. PREVIOUS INVESTIGATIONS AND REMOVAL ACTIONS

Previous investigations and removal activities conducted in the general Site area fall into three categories:

1. Construction of wetlands at the Jones Branch site in 1989.
2. Sampling and analysis conducted between 2002 and 2009 by the USDA FS culminating in CERCLA documents including PA or PA/SI reports for six of the ten individual sites comprising the aggregate Site and a single APA covering the remaining four component sites.
3. The application of treatment technologies between 1995 and 2010 by the Kentucky Division of Abandoned Mine Lands (KYDAML) and the USDA FS, in partnership with a number of local and federal agencies, and conservation organizations to begin to eliminate or reduce acidity from AMD at mine sites and streams within the lower Rock Creek watershed.
4. A biological assessment performed by the USDA FS' Southern Research Station, Center for Aquatic Technology Transfer in 2013 at six locations in the Rock Creek watershed.
5. The AML Safety Closures completed at the Rock Creek site – Numerous portal closures completed over the years by USDA FS and KYDAML, primarily for safety purposes, to keep humans from accessing the mines and avoiding the hazards.

The following section presents a brief summary of previous investigations completed at the site. Samples of affected media were collected and analyzed for typical mine drainage related contaminants. For each site, a table showing the breakdown of number of samples, identification, and year the samples were collected is presented along with a figure showing sample locations and constituents of concern detected above regulatory standards. Results from the PA/SIs completed at the sites are highlighted only. For detailed data summary, refer to **Appendix A** for historical (2002 – 2010) Site area analytical results for coal mine features, and site-specific PA/SI and APA and stream samples.

3.1. Preliminary Assessments and Site Inspections: 2002 through 2009

In 2002 through 2004, the USDA FS performed a coal mine features and AMD seeps inventory in the DBNF, including the Rock Creek abandoned mine sites. Coal mine features included mine openings (adits, portals, or shafts), coal refuse (waste) piles, ground surface subsidence, equipment, and structures. The efforts included water quality sampling of AMD (seeps and flows) and sedimentation ponds.

In 2004 through 2007, Big Momma Mine, Cabin Branch Mine, Grassy Fork Mine, Jones Branch Mine, Paint Cliff/Mine 16 Complex Mine, and Poplar Spring Hollow Mine were sampled again based on the results from the 2002 and 2004 sampling. In each instance, a CERCLA PA was first prepared by BAT, which concluded that the possibility of a release of a hazardous substance or pollutant or contaminant existed for the surface water, groundwater, and soil pathways. The follow up CERCLA SIs confirmed in each instance the release of one or more hazardous substances, such as one or more heavy metals, including cadmium (Cd), lead (Pb) and zinc (Zn), and the release of pollutants or contaminants including aluminum (Al) and iron (Fe), as well as elevated sulfate concentrations, together with the associated development of low pH levels in seep waters from portals and coal refuse piles.

In 2009, another sampling of Rock Creek and its relevant tributaries was conducted by Tennessee Valley Authority (TVA) personnel working on behalf of the USDA FS, primarily at strategic locations relative to drainage from mine areas. Data taken from these 2009 sampling analyses as well as the original coal mine features inventory were used by USDA FS to prepare an APA addressing releases of hazardous substances and pollutants or contaminants from Cooperative South Mine, Koger Fork Mine, Upper Rock Creek /Fidelity North Mine, and Water Tank Hollow Mine.

3.2. Interim Removal Actions: 2000 through 2009

In spring 2000, KYDAML implemented a pilot treatment/restoration project along the Lower Rock Creek watershed, which included White Oak Creek from Cabin Branch downstream to the confluence with Rock Creek at White Oak Junction, together with Rock Creek from White Oak Junction to the confluence with the Big South Fork. The Phase I project was located within Cabin Branch, Cooperative North Portal, and Jones Branch of White Oak Creek, and in Roberts Hollow, Paint Cliff, Poplar Spring Hollow, Koger Fork, and the mouth of Water Tank Hollow on Rock Creek.

Techniques used to accomplish reduction in acidity included monthly dosing with limestone sand, removal and treatment of acidic coal refuse from the banks of Rock Creek, installation of open limestone channels (OLCs), and installation of a modified vertical flow system at Paint Cliff. Existing culvert outlets from the main tributaries into White Oak Creek and Rock Creek were used as limestone sand dumping sites. The pilot project continued with monthly dosing until the fall of 2001 when it ended due to low flow conditions.

After two months of dosing, water quality at the mouth of Rock Creek changed from net acidic to net alkaline. After four months of dosing, water quality at the mouth of White Oak Creek changed from net acidic to net alkaline.

Based on the positive results of the pilot project, the decision was made to build permanent dosing stations in the main tributaries and continue with monthly dosing. Monthly dosing resumed in late winter 2002 with the increase in base flow. The rate of dosing continued to be double the calculated rate for the first year, and was reduced to the calculated rate thereafter. Dosing at double the calculated rate for the first year resulted in the accumulation of one year’s worth of neutralization potential in the streambed.

After two months of dosing, the net acid load from Rock Creek into the Big South Fork was reduced from a monthly average of 110 metric tons (121 US tons) per month before dosing to a monthly average of 0.063 metric tons (0.069 US tons) per month. After four months of dosing the net acid load entering Rock Creek from White Oak Creek, for the months having flow, was reduced from an average of 13 metric tons (14 US tons) per month before dosing to an average of 0.015 metric tons (0.017 US tons) per month.

Phase II work was also performed at the same sites in 2002 to 2005 and Phase III was completed in 2008 to 2009. The broad outcome of the abatement project was a major reduction of acid loading from White Oak Creek into Rock Creek and from Rock Creek into the Big South Fork of the Cumberland River in each instance after completion of the abatement project. While the abatement project addressed the reduction in releases of acidity, as well as iron and aluminum concentrations, effects on the levels of trace metals in the mine drainage and stream systems were not known because they were not examined (Carew et al., 2005).

3.3. Cabin Branch and Unnamed Branch Mines

3.3.1 Previous Investigations

In November 2001, as part of a Rock Creek water quality study, BAT collected seepage water and coal refuse samples within the Cabin Branch Mines Site. A grab sample of water was collected from seepage emerging from a coal refuse pile in a source area on the slope west of Cabin Branch. Two coal refuse samples were collected directly from the aforementioned coal refuse pile at a depth of 6 to 18 inches using a shovel and hand auger. Laboratory analysis of the seepage water sample indicated that exceedances of four metal concentrations (aluminum, iron, nickel, and zinc) were detected. The screening levels were based on the State of Kentucky surface water standards. Laboratory analysis of the coal refuse samples indicated arsenic concentrations of 18.1 and 20.2 milligrams per kilogram (mg/kg), which exceeded the USEPA Region 9 preliminary remediation goal (PRG) of 1.6 mg/kg. The iron concentration in the first sample (264,000 mg/kg) also exceeded its PRG of 100,000 mg/kg. Refer to the PA/SI for detailed information.

On November 30 and December 1, 2004, an SI that included seep water, seep sediment, and coal refuse sampling was conducted by BAT at the Cabin Branch Mines Site (see **Table 1**). Three source areas were identified as source areas A, B, and C. Source areas A and B were located along Cabin Branch, while source area C was located along an unnamed tributary of White Oak Creek (or "Unnamed Branch" as referred to in this report). The analytical results collected from the source areas' seep water at the Cabin Branch Mines Site exhibited elevated sulfate, acidity, and heavy metals, indicating the mine portal seep water has been impacted by AMD and exceeds State of Kentucky surface water standards and USEPA Region 4 ecological risk assessment fresh water surface water screening values. Metals detected above surface water standards included aluminum, beryllium, copper, iron, nickel, and zinc (see **Figure 4**). BAT concluded that the impact of low pH and high metals concentrations from mine seep water entering Cabin Branch was negatively contributing to the surface water pathway to Rock Creek targets. BAT opined that the source waste materials at the Cabin Branch Mines Site were impacting Cabin Branch and Rock Creek, and that they should be considered a water quality problem.

Analytical data from the sediment samples indicated high concentrations of metals, particularly aluminum and iron. Iron levels ranged from 13,200 mg/kg to 99,600 mg/kg, and aluminum levels ranged from 462 mg/kg to 47,660 mg/kg, but neither exceeded USEPA Region 9 PRGs, both industrial goals being 100,000 mg/kg. Arsenic levels were found to be high in all samples; however, arsenic is naturally elevated in the site vicinity's soils. Low pH and increased sulfate concentrations were also present in the sediment. These data indicated that the sediments at the mine seep locations were impacted by AMD.

The coal refuse samples also indicated high concentrations of iron and aluminum. Iron concentrations ranged from 7,430 mg/kg to 39,600 mg/kg but did not exceed the PRG of 100,000 mg/kg. Aluminum concentrations ranged from 1,300 mg/kg to 5,790 mg/kg but did not exceed the PRG (100,000 mg/kg). Arsenic levels were found to be high in all samples; however, arsenic is naturally elevated in the site vicinity's soils. The pH ranged from 3.50 to 6.20. These data suggested that the coal refuse piles located throughout the Cabin Branch source areas contained high levels of metals and low pH, which is consistent with the results of the sediment and seep water samples and with the impact from AMD.

BAT concluded that the soil exposure pathway should be considered threatened and already severely impacted by hazardous substances at the Cabin Branch Mines Site. The concentrations of metals detected, as compared to the PRGs, indicated the presence of these substances in the existing refuse piles. BAT opined that there was a significant possibility that these substances were also present in the surrounding soil from the transport of storm water run-off and seepage from mine portals.

From June 22 through June 25, 2009, two surface water samples were collected from Cabin Branch. Results showed exceedances for eight metals, including beryllium, cadmium, aluminum, cobalt, iron, nickel, lead, and zinc.

3.3.2 Previous Interim Removal Actions

Dosing with limestone sand began in Cabin Branch in January 2001 following the limestone sand dumping pilot project. The dosing site was moved from White Oak Creek at the mouth of Cabin Branch to an existing culvert located approximately 100 yards (100 meters) upstream in Cabin Branch. A 400-foot (122 meter) OLC was constructed from the deep mine portals, contributing the majority of the AMD in the Cabin Branch watershed, down to Cabin Branch in July 2001 (Phase I). An existing road was upgraded, and a limestone sand dumping station was constructed approximately 3000 feet (914 meters) farther upstream from the existing dosing station in the fall of 2001. Dosing began at the upstream dosing site and ceased at the downstream dosing site. In the fall of 2002, construction began on Phase II of the Rock Creek AMD abatement project. Open limestone channels totaling 4000 feet (1220 m) were installed in Cabin Branch in late fall 2003. A limestone channel 500 feet in length was constructed at the Cabin Branch portal discharge. The portal discharge was diverted into the OLC before flowing into Cabin Branch. Limestone riprap was placed directly in the tributary from the first source of AMD in Cabin Branch for a distance of 2700 feet (823 m) to the mouth of Cabin Branch.

The OLCs were lined with a few inches (8 centimeters [cm]) of limestone sand before the placement of the crushed limestone riprap. The crushed limestone was 4 inches (10 cm) to 9 inches (23 cm) in size in low flow areas. In high flow areas, the crushed limestone was 9 inches (23 cm) to 18 inches (45 cm) in size. Limestone sand dumping in Cabin Branch ceased in fall of 2003 after installation of the OLCs.

During Phase II of the Rock Creek project, 2000 feet (610 m) of OLCs were installed in the unnamed tributary (or Unnamed Branch) of White Oak Creek from the mine openings to the tributary and 1500 feet (457 m) to the mouth of the tributary. The OLCs were lined with a few inches (8 cm) of limestone sand before placement of the crushed limestone riprap. The crushed limestone was 4 inches (10 cm) to 9 inches (23 cm) in size in low flow areas. In high flow areas, the crushed limestone was 9 inches (23 cm) to 18 inches (45 cm) in size.

In the recent past, the USDA FS has periodically dumped limestone sand at some of the dosing stations to provide additional but temporary water treatment.

3.4. Big Momma Mine

3.4.1 Previous Investigations

In December 2002, TVA conducted surface water quality measurements on the seep water at Big Momma Mine. The pH readings collected at five locations along the seep ranged from 5.0 to 6.0, which were below water quality criteria (2001 USEPA Region 4 Waste Management Division Freshwater Surface Water Screening Values for Hazardous Waste Sites has pH criteria of 6.5 to 9.0 for support of aquatic species).

In November 2006 and May 2007, an SI was conducted by BAT that included sampling seep water, surface water, and sediment (see **Table 2**). Seven water samples were collected for analysis of selected water quality parameters from surface water near the Big Momma Mine seeps and from White Oak Creek near the confluence with the seep flow. The analytical results indicated surface water collected from the source area at the Big Momma Mine site exhibited increased sulfate, acidity, heavy metals, and low pH, which indicated the seep water was impacted by AMD (**Figure 5**). There were no significant differences in measurable analyte concentrations in White Oak Creek above and below the point of seep entry that would indicate a major seep impact on the creek; however, the laboratory minimum detection limit for nine CERCLA hazardous substance metals was higher than the corresponding screening levels. BAT concluded that the low pH, high metals, and high sulfate concentrations from mine seep water were contributing negatively through the surface water pathway to the impairment of White Oak Creek and ultimately Rock Creek targets.

Seven sediment samples were collected from Big Momma Mine seeps, and from White Oak Creek. Analytical data from the seep sediment samples indicated high concentrations of metals, particularly iron. Iron levels ranged from 55,900 mg/kg to 187,000 mg/kg in the seep sediment samples. Low pH levels were also present in the seep sediment. These data indicate that the seep sediment sample locations have been impacted by AMD. An upstream sediment sample from White Oak Creek contained a concentration of 5.19 mg/kg of arsenic (As), which exceeds the industrial soil PRG. BAT concluded that the results of the sampling conducted under their SI indicated that the surface water at the Big Momma Mine site was impacted by AMD, and was above regulatory limits for aquatic habitat criteria and drinking water for several constituents, but contained no CERCLA hazardous substances.

On June 24, 2009, one surface water sample was collected downstream of Big Momma, and the results showed aluminum, iron, nickel (Ni), and lead detections above regulatory standards.

3.4.2 Previous Removal Actions

There were no significant efforts of AMD remediation at the Big Momma Mine Site, other than erosion control and OLC construction from the seeps to the road performed by the Commonwealth of Kentucky.

3.5. Cooperative South Mine

3.5.1 Previous Investigations

During the winters of 2002 through 2004, TVA was contracted by USDA FS to conduct an inventory of coal mine features on the DBNF. As part of this inventory, surface water samples were collected from the coal mine features that were associated with flowing water (see **Table 3** and **Figure 6**). Additionally, TVA was contracted in June 2009 to collect surface water samples from White Oak Creek, Rock Creek, and 12 other Rock Creek and White Oak Creek tributaries, many of the same areas assessed during the coal mine features inventory. A total of seven water samples were collected in the area of the Cooperative South Mines and compared to two samples collected for reference concentrations and/or calculated surface water standards or criteria.

The 2009 analytical results indicated that the surface water samples collected in areas associated with historical mining activities in the Cooperative South Mine area had several surface water criteria exceedances, including pH, beryllium (Be), cadmium, aluminum, iron, nickel, and lead. In addition, conductivity, sulfate, arsenic, barium (Ba), cobalt (Co), copper (Cu), manganese (Mn), and zinc results indicated concentrations that exceeded measured reference levels. The Cooperative South sample results indicated that surface water was being significantly impacted by AMD.

3.5.2 Previous Interim Removal Actions

There were no efforts of AMD remediation at the Cooperative South Mine Site.

3.6. Jones Branch Mine

3.6.1 Previous Investigations

The USDA FS implemented a watershed study at this site in 1959 with projects following in the early 1960s. Partial success was seen with the establishment of some trees on the waste dumps; however, water quality did not improve in Jones Branch (BAT, November 13, 2009).

In November 2001, BAT collected water, coal refuse, and sediment samples at various locations within the Jones Branch Mines Site as part of an initial sampling of various mine sites located within the Rock Creek watershed. Water quality samples were collected as grab samples from the constructed wetland in Jones Branch and from seepage emerging from coal refuse pile C (as shown in the BAT PA/SI). Sediment samples were collected on the edge of and within standing water to determine what contaminants had settled out of the water column. The analytical results of the seep and wetland outfall water samples indicated low pH (3.12. to 3.29) and exceedances in dissolved metal concentrations including aluminum, beryllium, cadmium, chromium (Cr), lead, nickel, and zinc.

Samples of coal refuse were collected directly from a coal refuse pile in source area C at a depth of 6 to 18 inches using a shovel and hand auger. Where vegetation was present, soil samples were taken at depths below the root zone. The analytical results of the sediment sample, taken at the wetland outfall, indicated that the detected arsenic and iron concentrations exceeded the corresponding PRG industrial soil screening level, while the soil samples at source area C detected exceedances in only arsenic concentrations.

On December 1, 2004, BAT performed an SI that included surface water, sediment, and coal refuse sampling within the Jones Branch Mines Site source areas (see **Table 4**). BAT collected two water samples from the outlet of the mine seeps for analysis of selected water quality parameters. The analytical results indicate seep water collected from the source area at the Jones Branch Mines Site exhibited elevated sulfate, acidity, heavy metals, and low pH (2.78 to 3.60), which indicated the seep water was impacted by AMD. Metals of note included aluminum, beryllium, cadmium, chromium, nickel, and zinc, which were all above water quality criteria and/or screening levels (see **Figure 7**).

The two sediment samples indicated high concentrations of metals, particularly arsenic and iron. The arsenic levels were 52.5 mg/kg and 45 mg/kg, which exceeded the PRG for industrial soils. The iron concentration of one of the samples was 240,000 mg/kg. Low pH and increased sulfate concentrations were also present in the sediment. Data from the coal refuse soil samples indicated high concentrations of arsenic, aluminum, and iron. Arsenic levels in the samples ranged from 7.07 mg/kg to 25 mg/kg, which exceeded the PRG for industrial soils. Iron levels ranged from 8,060 mg/kg to 25,100 mg/kg. Low pH and increased sulfate concentrations were also present in the coal refuse.

On June 23, 2009, one sample collected by TVA in Rock Creek and approximately 125 feet below the confluence of Jones Branch and White Oak Creek showed detections of aluminum and iron above regulatory standards.

3.6.2 Previous Interim Removal Actions

The USDA FS implemented a watershed study at this site in 1959 with projects following in the early 1960s. Partial success was seen with the establishment of some trees on the waste dumps; however, water quality did not improve in Jones Branch.

In an effort to improve water quality and protect aquatic habitat, the USDA FS constructed 11,000 square feet of a wetland to treat Jones Branch AMD in the spring of 1989. Metal concentrations and acidity of AMD effluents were reduced substantially during the first year of treatment; however, treatment efficiency of the wetland was drastically reduced thereafter due to insufficient utilization of treatment area, inadequate alkalinity production, and metal overloading.

In February 2003, during Phase II of the Rock Creek project at Jones Branch, 8000 feet (2440 m) of OLCs were installed, including 4000 feet (1220 m) in the main stem of Jones Branch, starting 500 feet (152 m) above the farthest upstream portals and continuing downstream for 4000 feet (1220 m). Two side tributaries to the main stem were lined with limestone for a distance of 300 feet (91 m) and 500 feet (152 m). OLCs were installed from the underground mine portals to the main stream. The OLCs were lined with several inches (8 cm) of limestone sand before placement of the crushed limestone riprap. The crushed limestone was 4 inches (10 cm) to 9 inches (23 cm) in size in low flow areas. In high flow areas, the crushed limestone was 9 inches (23 cm) to 18 inches (45 cm) in size. Limestone sand dumping in Jones Branch ceased after installation of the OLCs during Phase II of the Rock Creek project. The pH in Jones Branch prior to construction ranged from 2.5 to 4.3. After installation of the limestone channels, the pH has ranged from 4.0 to 6.3.

3.7. Upper Rock Creek Fidelity North Mine; Rock Creek; and White Oak Creek

3.7.1 Previous Investigations

During the winters of 2002 through 2004, TVA was contracted by the USDA FS to conduct an inventory of coal mine features on the DBNF. As part of this inventory, surface water samples were collected from the coal mine features that were associated with flowing water (see **Table 5**). Additionally, TVA was contracted in June 2009 to collect surface water samples from Rock Creek and 12 other Rock Creek and White Oak Creek tributaries, many of the same areas assessed during the coal mine features inventory. Three of the samples occurred in the area of the Fidelity North Mine in the Upper Rock Creek (URC-1, URC-2, and URC-839). The water samples collected in the Upper Rock Creek mining area had several surface water criteria exceedances (see **Figures 8** and **9**). In sample location URC-1, Fe and conductivity exceeded criteria; whereas sulfate, aluminum, barium, cobalt, manganese, and nickel exceeded locally measured reference levels. In location URC-2, only aluminum exceeded the surface water criterion; however, copper and iron exceeded reference concentrations. At location URC-839, pH, conductivity, aluminum, cadmium, chromium, copper, iron, and lead exceeded surface water criteria; and sulfate, arsenic, manganese, and zinc exceeded reference levels.

3.7.2 Previous Removal Actions

No effort of AMD remediation has been performed at the Upper Rock Creek Fidelity North Mine site.

3.8. Paint Cliff Mine and Roberts Hollow Mine

3.8.1 Previous Investigations

In November 2001, BAT collected water and coal refuse samples at various locations within the Rock Creek watershed. A water quality sample was collected as a grab sample from seepage emerging from a coal refuse pile. No sediment samples were collected. Coal refuse samples were collected directly from the coal waste pile at a depth of 6 to 18 inches using a shovel and hand auger. Where vegetation was present, soil samples were taken at depths below the root zone. Analytical results from the samples indicated exceedances in metal concentrations including aluminum, beryllium, iron, nickel, and zinc for the seepage water and aluminum, arsenic, and iron in the coal refuse.

In 2002, the TVA personnel working under USDA FS direction conducted a coal mine features inventory in the Rock Creek abandoned mines area. Water quality data of mine seeps reported some low pH values of seep water and surface water (**Tables 6** and **7**).

In November 2004, BAT performed a PA/SI on the Paint Cliff/Roberts Hollow area including seep water, seep sediment, and coal refuse sampling. BAT collected three water samples from the outlet of the mine seeps for analysis of selected water quality parameters. Water quality readings of the seep water were recorded in the field prior to collecting each sample. Values for dissolved oxygen (in percent saturation) were found to be as high as 524.8 percent. In addition, pH values were measured higher (10.16 to 13.48) than the reference criteria of 6.5 to 9.0 for support of aquatic species. The analytical results indicated seep water collected from the source area at the Paint Cliff/Roberts Hollow area exhibited increased sulfate, acidity, heavy metals, and low pH, which indicated the seep water had been impacted by AMD. Metals of note included aluminum, beryllium, chromium, copper, iron, nickel, selenium, and zinc, which were all above water quality criteria and/or screening levels (**Figures 10** and **11**). BAT concluded that the impact of low pH and high metals concentrations from mine seep water entering the Paint Cliff/Roberts Hollow area was negatively contributing to the surface water pathway to Rock Creek targets.

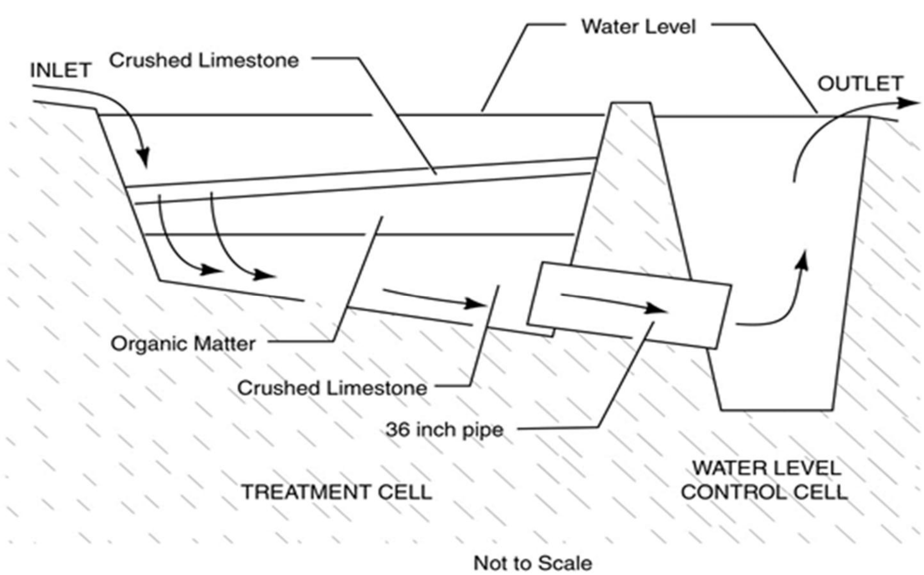
In June 2009, one surface water sample collected by TVA downstream from Roberts Hollow showed detections of aluminum and iron above water quality criteria.

Analytical data from the sediment samples indicated high concentrations of metals, particularly arsenic and iron, above the PRG. Arsenic levels ranged from 54.9 to 73.1 mg/kg, while iron levels ranged from 54,900 mg/kg to 136,000 mg/kg. Low pH and increased sulfate conditions were also present in the sediment. BAT opined that these data indicated that the sediment at the mine seep locations had been impacted by AMD.

Data from the coal refuse soil samples indicated concentrations of arsenic above the PRG. Levels ranged from 5.93 mg/kg to 36.6 mg/kg. According to BAT, these data suggested that the coal refuse piles located throughout the Paint Cliff source area showed characteristics of contributing to the source of AMD within Rock Creek.

3.8.2 Previous Interim Removal Actions

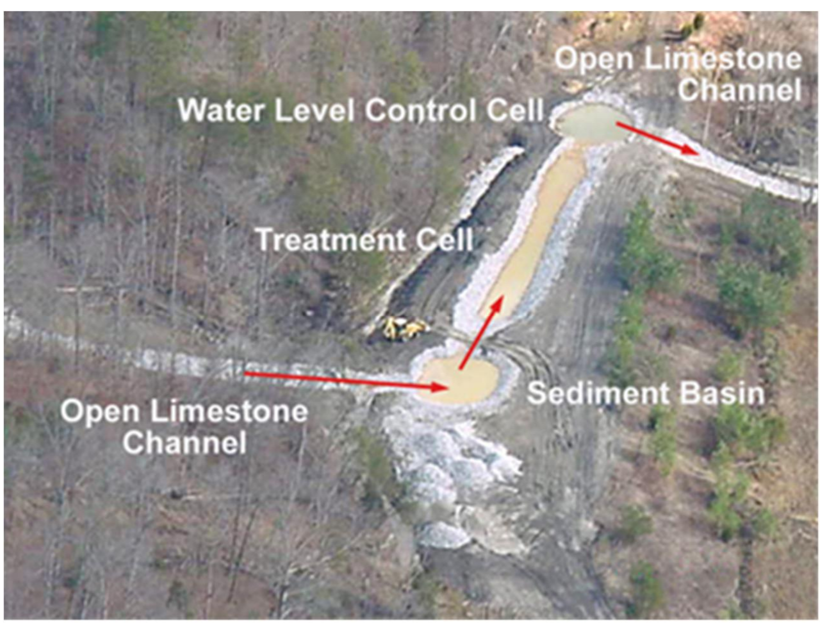
In 1983, the KYDAML funded a remediation project at the Paint Cliff site. It included the sealing of six mine openings, the extinguishing of burning refuse, the grading of slopes (190,000 cubic yards moved), the removal of gullies, and revegetation. The site received extensive reclamation efforts in the two initial Rock Creek projects. In 2009, a modified vertical flow wetland was installed, as well as OLCs directing acid mine water to and from a vertical flow wetland. An OLC was installed to intercept and carry water from the toe of the refuse fill and from a deep mine discharge to a sediment basin before entering a vertical flow system. The modified vertical flow system was installed at the Paint Cliff Site that eliminated the use of pipes in the bottom of the treatment cell and that eliminated the standpipe to control water levels and exclude atmospheric oxygen (see below).



The modified design includes a treatment cell followed by a second cell. A smooth wall 36-inch pipe installed at the bottom of the treatment cell connects the treatment cell to the second cell. Due to the direct connection between the treatment cell and the second cell via the 36-inch pipe, the spillway of the second cell controls the water level of the treatment cell. The positive slope on the treatment cell and the 36-inch outlet pipe towards the second cell encourages flow of aluminum precipitates from the treatment cell into the second cell. The second cell was excavated deeper than the bottom of the 36-inch pipe to provide storage for any precipitates flushed into it. With adequate freeboard in the treatment cell, as precipitate begins to clog the limestone bed (LB), the water level rises in the treatment cell increasing head and flushing the precipitate into the second cell. The elimination of small diameter pipes and the flow-through design of the treatment cell was intended to minimize clogging with precipitates.

After a few months of use, the spillway on the cell controlling the water elevation in the treatment cell had to be lowered to prevent flow from exiting the emergency spillway of the treatment cell. As precipitates accumulated in the treatment cell, more head was required to drive the water through the system. After lowering the spillway of the second cell, the water elevation of the treatment cell was about a foot higher than the adjusted water elevation in the second cell. This adjustment eliminated flow out of the emergency spillway in the treatment cell except during high flow events in late winter and early spring. The system was undersized to handle the entire flow during high flow events. Diversion of the excess flow into a second vertical flow system was intended to solve this problem. An increase of freeboard in the treatment cell allowed it to handle larger flows with the increase in head. If the modified design proved to be successful over a longer period of time, the plan was to install a second treatment system in series with the first.

An OLC 100 feet in length intercepts the AMD before discharging into the sediment basin (see photo below). Flow proceeds from the sediment basin into the treatment cell. Water is discharged from the vertical flow system into an OLC, 100 feet in length. The water then flows across the highway and through 500 feet of low gradient limestone lined ditch before discharging into Rock Creek. A 500-feet ditch was installed along the highway that did not function as treatment due to clogging with precipitates. An additional 500 feet (152 m) of OLC was installed in a natural drain above the treatment cell. The natural drain is impacted by acidic drainage from the refuse fill. Water was diverted from the vertical flow treatment cell in June and July 2003 during construction of the additional OLC.



The pH values ranged from 2.4 to 3.9 for the 16 sampling dates that had flow prior to construction of the vertical flow system. The pH values ranged from 4.8 to 6.2 for the 17 sampling dates after installation of the vertical flow system. Acidity decreased from an average of 677 mg/L calcium carbonate ($CaCO_3$) to an average of 25 mg/L $CaCO_3$ after installation of the vertical flow system. Alkalinity increased from 0 to an average of 8 mg/L $CaCO_3$ after installation of the OLC. Net acidity was reduced 96% from an average of 677 mg/L $CaCO_3$ to an average of 26 mg/L $CaCO_3$ post construction. The discharge was net acidic until installation of the vertical flow system when it became net alkaline for 10 of the 17 sampling periods post construction. Net acid loading was near zero post construction with the exception of the September 25, 2001 sampling date when flow increased after a low flow period.

During the sampling period in July 2005, acidity values were 1,531 mg/L $CaCO_3$ equivalent entering the treatment system and 470 mg/L $CaCO_3$ equivalent at the discharge end of the treatment system. It was concluded that the most economical and least maintenance intensive method for additional treatment at this site was installation of a series of two self-flushing limestone ponds. This was a relatively new technology that was being used on a large scale in Pennsylvania to treat some of the worst AMD sites in that state. The technology had not been tried in Kentucky. It has several advantages over other treatment methods. Since it is self-flushing, clogging problems associated with vertical flow wetlands in waters with high aluminum concentrations such as those found at Paint Cliff are non-existent. Maintenance is far less than an active treatment system like the Aqua-fix treatment method. Limestone is used in the treatment cells instead of hydrated lime or quick lime, so pH levels remain below 8.5, eliminating concerns with vandalism or accidental releases of reagents into the environment. Additionally, the treatment cells can be sized so that maintenance is infrequent. An aerobic polishing wetland is needed prior to the discharge of the AMD into Rock Creek to settle out the iron and aluminum precipitate. Unfortunately, due to the newness of the technology and lack of knowledge regarding possible consequences, the cells installed at this site were constructed without liners. As a result, water has seeped into the hillside and emerges as seeps above and adjacent to the highway. Also, the efficacy of this system has since been reduced due to insufficient dredging of the sediments and refreshment of the limestone.

3.8.2.1. Coal Refuse Pile Removal

The Rock Creek Clean Water Action Plan Project involved the removal of 5,000 cubic yards of highly acidic coal mine refuse from the Paint Cliff coal load out site. The goal of the Rock Creek Project was to show a demonstrable reduction in sediment and acidity entering Rock Creek and to return the land where the coal processing refuse dumps are located to a vegetated state compatible with the surrounding land. The refuse was a significant source of sedimentation and AMD into Rock Creek, as well as a visual blight to the surrounding forested area. The refuse was loaded and hauled to an existing refuse area in Roberts Hollow.

The existing fill area in Roberts Hollow had sparse vegetation on the lower slope area due to acidic groundwater seepage generated by the acid forming material located on the upper slope of the refuse fill. The plan was to use the treated refuse from the Water Tank Hollow site to reclaim and revegetate the lower slope of the Roberts Hollow fill site. A cutoff trench was excavated above the lower slope being used as a fill area for the treated refuse to divert acidic groundwater away from the new fill. The acidic groundwater intercepted by the diversion ditch was treated with limestone riprap placed in the excavated channel. The refuse was placed in 6-inch (15-cm) to 8-inch (20-cm) lifts near the toe of the existing refuse fill. Foundation benches were excavated and an agricultural limestone barrier was placed prior to placement of the refuse. Agricultural limestone was incorporated into each lift. Suitable borrow material for soil cover over the treated and compacted refuse was found in the fill area and was placed 2 feet (0.6 m) thick on top of the final lift of refuse. The refuse fill area was seeded with a mix of acid tolerant warm and cool season grasses and legumes and planted with bare rootstock trees.

In 2000, a limestone channel 1000 feet in length was constructed immediately above the refuse fill area at the Roberts Hollow site. A limestone channel 800 feet in length was installed in the natural drain on the southeast side of the Roberts Hollow fill area. The limestone channels in Roberts Hollow intercept acidic water from the upper slopes of the refuse fill area, divert acidic water away from the new fill, and provide treatment to the water before discharging into the main tributary and Rock Creek.

In the fall of 2002, construction began on Phase II of the Rock Creek AMD abatement project. An on-bench acidic pond was eliminated in Roberts Hollow. Dosing with limestone sand was conducted monthly with permanent dosing stations established upstream in the impacted tributaries. Dosing of the tributaries with sand-sized limestone particles continued but was reduced as the reclamation in the tributaries was accomplished. The OLCs were lined with several inches (8 cm) of limestone sand before placement of the crushed limestone riprap. The crushed limestone was 4 inches (10 cm) to 9 inches (23 cm) in depth in low flow areas. In high flow areas, the crushed limestone was 9 inches (23 cm) to 18 inches (45 cm) in depth.

3.9. Poplar Spring Hollow Mine

3.9.1 Previous Investigations

In November 2001, BAT collected one seep water and two coal refuse samples at a source area at Poplar Hollow. In 2002, the TVA conducted a coal mine features inventory in the Rock Creek abandoned mines area. Water quality data of mine seeps reported low pH values of seep water and surface water in the Poplar Spring Hollow Mines Site area.

On November 22, 2004, BAT performed an SI that included the collection of three water, three sediment, and three coal refuse samples from the outlet of the mine seeps for analyses (see **Table 8**). The analytical results indicated seep water collected from the source area at the Poplar Spring Hollow site exhibited increased sulfate, acidity, heavy metals, and low pH, which indicated the seep water was impacted by AMD. Metals of note include aluminum, beryllium, cadmium, chromium, copper, iron, lead, nickel, and zinc, which were all above water quality criteria and/or screening levels (see **Figure 12**).

Analytical data from the sediment samples indicate high concentrations of metals, particularly arsenic and iron. Arsenic levels ranged from 36.4 mg/kg to 73.1 mg/kg and iron levels ranged from 52,800 mg/kg to 136,000 mg/kg. Low pH and increased sulfate conditions were also present in the sediment. These data indicated that the sediments at the mine seep locations were impacted by AMD.

The coal refuse soil samples indicated high concentrations of arsenic. Arsenic levels range from 6.68 mg/kg to 32.4 mg/kg. These data suggested that the coal refuge piles located throughout the Poplar Spring Hollow source area showed characteristics of attributing to the source of AMD within Rock Creek. The concentrations of metals detected, as compared to the PRGs, indicated the presence of these substances in the existing refuse piles.

3.9.2 Previous Removal Actions

Previous reclamation efforts in Poplar Spring Hollow have routed the AMD through OLCs along the mine bench and down the out slope to the receiving stream. Dosing with limestone sand began in Poplar Spring Hollow in November 2000 following construction of a limestone dosing station 600 feet upstream from the confluence of Poplar Spring Hollow and Rock Creek. OLCs were installed during Phase I of the Rock Creek project at the Poplar Spring Hollow portal site. An OLC 130 feet (40 m) in length was installed at the mouth of Poplar Spring Hollow.

In the fall of 2002, construction began on Phase II of the Rock Creek AMD abatement project. A 2-acre (0.81-ha) landslide was stabilized and revegetated in Poplar Spring Hollow. Dosing of the tributaries with sand-sized limestone particles continued but was reduced as the reclamation in the tributaries was accomplished. In May 2003, during Phase II of the Rock Creek project at Poplar Spring Hollow, a total of 2500 feet (762 m) of OLCs were installed from the mine openings to the tributary and within the main stem to the mouth of the tributary. Limestone channels were installed from the deep mine portals to the tributary and in the main tributary from the limestone dosing station to the mouth of Poplar Spring Hollow. Limestone dosing ended in Poplar Spring Hollow in May 2003 with the installation of the limestone channels.

3.10. Koger Fork Mine

3.10.1 Previous Investigations

During the winters of 2002 through 2004 and again in June 2009, the TVA collected surface water samples from the coal mine features that were associated with flowing water from White Oak Creek, Rock Creek, and 12 other Rock Creek and White Oak Creek tributaries, including a total of ten samples in the Koger Fork area (see **Table 9**). Six were surface water samples, and four were associated with coal mine features.

Three of the surface water samples collected in the Koger Fork mined area had measured concentrations that exceeded surface water criteria for pH. Three of the four coal mine features exhibited pH values of 1. All ten samples exceeded water quality criteria established for the investigation in at least several of the measured parameters, which included aluminum, arsenic, beryllium, cadmium, total chromium, cobalt, conductivity, copper, iron, lead, magnesium (Mg), manganese, nickel, pH, potassium (K), selenium (Se), sodium (Na), sulfate, vanadium (V), and zinc. Metals detected above surface water criteria are shown in **Figure 13**.

Additional surface water samples were collected in 2009 and detections, above surface water criteria were noted for beryllium, cadmium, aluminum, copper, iron, lead, and selenium.

3.10.2 Previous Removal Actions

No effort of AMD remediation has been performed at the Koger Fork site; however, coal waste was taken from the Water Tank railroad coal refuse waste dump and placed into a ridge top repository at the headwaters of Koger Fork.

3.11. Water Tank Hollow Mine

3.11.1 Previous Investigations

During the winters of 2002 through 2004 and again in June 2009, the TVA collected surface water samples from the coal mine features that were associated with flowing water from White Oak Creek, Rock Creek, and 12 other Rock Creek and White Oak Creek tributaries, including two samples taken at the confluence of Water Tank Hollow and Rock Creek (see **Tables 5** and **10**).

Analytical results of the samples indicated exceedances above reference levels of conductivity, cadmium, aluminum, barium, cobalt, copper, iron, manganese, nickel, lead, antimony (Sb), vanadium, and zinc (**Figure 14**). In addition, aluminum and lead concentrations were above the identified surface water criteria in the 2009 sampling.

3.11.2 Previous Removal Actions

Open limestone channels were installed during Phase I of the Rock Creek project at the Water Tank Hollow refuse removal site. In the fall of 2000, approximately 20,000 cubic yards of highly acidic coal mine refuse was removed from the Water Tank Hollow site (adjacent to Rock Creek). The refuse was hauled to an existing sparsely vegetated fill area in Roberts Hollow, treated with agricultural limestone at rates determined by soil testing, and placed in compacted lifts. The refuse was a significant source of sedimentation and AMD into Rock Creek, as well as a visual blight to the surrounding forested area.

At the Water Tank Hollow site, a natural drainage feature was encountered during excavation of the coal mine refuse from the banks of Rock Creek. An OLC was installed in the steep natural drain encountered during excavation of the refuse. Acid seeps were encountered near the toe of the slope after removal of the refuse from the Water Tank Hollow site. An OLC was installed along the toe of the slope picking up the acid water and directing it through the limestone before discharging into Rock Creek.

Dosing with limestone sand was conducted monthly with permanent dosing stations being established upstream in the impacted tributaries. The OLCs were lined with several inches of limestone sand before placement of the crushed limestone. The crushed limestone was 4 inches (10 cm) to 9 inches (23 cm) in depth except for high flow areas. In high flow areas, the crushed limestone was 9 to 18 inches in depth.

3.12. Grassy Fork Mine

3.12.1 Previous Investigations

In 2002, the TVA conducted a coal mine features inventory in the Rock Creek abandoned mines area, which included surface water samples of coal refuse seeps along Grassy Fork (see **Table 11**). Water quality data of the seeps reported low pH values (approximately 4.0).

In November 2006, BAT sampled seep and stream water, seep sediment, and coal refuse material and resampled seep and stream water on May 10, 2007 at the Grassy Fork Mines site. A total of eight samples were collected at eight locations. The analytical results of mine seep water samples collected from along Grassy Fork (including mine portals) exhibited elevated levels of aluminum and nickel. Water samples taken from Rock Creek, above and below the confluence with Grassy Fork, exhibited elevated levels of aluminum and iron and pH readings below the criteria for support of aquatic species (**Figure 15**). The results indicated that the surface water of both Grassy Fork and Rock Creek were impacted by AMD, and some parameters tested exceed both aquatic habitat criteria and drinking water standards. Differences in analyte concentrations in Rock Creek, above and below the confluence with Grassy Fork, suggested that Grassy Fork adds iron and aluminum to Rock Creek. Many of the analytes (aluminum, beryllium, cadmium, copper, lead, mercury, selenium, silver and thallium) were reported as non-detects in the laboratory reports for some of the samples collected, yet the actual concentrations of these metals may have exceeded the applicable water quality criteria and/or screening levels. This could not be determined from the data, since the minimum laboratory reporting limit was higher than the applicable criteria.

Analytical data from the sediment/coal refuse samples indicated high concentrations of metals; particularly arsenic, which was detected at levels ranging from 1.93 mg/kg to 5.49 mg/kg. Low pH and increased sulfate concentrations were also present in some of the sediment samples. These data indicated that the sediment was impacted by AMD.

Analytical data from the coal refuse samples indicated high concentrations of metals, particularly arsenic, which ranged in concentrations from 2.07 mg/kg to 14.4 mg/kg. Low pH and increased sulfate concentrations were also present in some of the sediment and coal refuse samples. These data indicated that the coal refuse sample locations were impacted by AMD. Additionally, it appears that the levels of arsenic in the coal refuse samples collected near sediment samples in Grassy Fork had corresponding high levels associated with them.

In June 2009, a surface water sample was collected at the mouth of Grassy Fork (downstream), and the results showed detection of aluminum above surface water criteria.

3.12.2 Previous Removal Actions

No efforts at remediation have been conducted on the Grassy Fork Mine site.

4. SUPPLEMENTAL SITE INVESTIGATIONS: NATURE & EXTENT OF CONTAMINATION DEFINITION

Analytical results for surface water, refuse pile toe pore water (groundwater), and sediment samples collected during the 2002 through 2014 sampling events were evaluated to establish the nature and extent of AMD impact at each of the sites. Previous PA/SI data were reviewed and results showing exceedances are summarized in **Figures 4 through 15** and **Appendix A**. Site visits were conducted in October and November 2013 to identify data gaps and develop a sampling and analysis work plan that was followed to adequately characterize the nature and extent of contamination at the Site and establish a basis for developing the EE/CA. Site visit and EE/CA investigation photographs and notes are provided in **Appendix B.** The 2014 analytical results are summarized for each site in **Tables 12 through 21**. The 2014 laboratory analytical results package are contained in **Appendix C**. The results were compared to federal and State of Kentucky standards to identify contaminants of interest (COI) at each of the sites.

For surface water samples, the pH value is compared to the Kentucky Surface Water Standards for a warm water aquatic habitat, which require the pH to be between 6.0 and 9.0. The applicable criteria for silver, arsenic, cadmium, chromium, copper, iron (depending upon if aquatic life has been shown to be affected), mercury, nickel, lead, and selenium are from the Kentucky Surface Water Standards for a warm water habitat. Barium and sulfate values are compared to the Kentucky Surface Water Standards for a domestic water supply source. For conductivity, the sample value is compared to the USEPA's July 2011 Final Appalachian Mining Guidance, which recommends the conductivity to be below 500 microsiemens per centimeter (µS/cm). The applicable criteria for aluminum, beryllium, antimony, and thallium are from the USEPA Region 4's Ecological Risk Assessment Fresh Water Surface Water Screening Values. Lastly, the upper threshold for manganese of 0.50 milligrams per liter (mg/L) is from the USEPA's National Secondary Drinking Water Regulations' Maximum Contaminant Levels (MCLs).

For the sediment samples, the USEPA Region 4 May 2014 Generic Removal Management Levels (RMLs) for Residential Soil were used as the applicable criteria for each analysis. For the pore-water samples, which for comparison purposes are categorized as groundwater samples, the analysis results for each sample were compared to the USEPA Secondary Drinking Water Standard, the MCL according to the USEPA National Primary Drinking Water Regulations, and the MCL Goal (MCLG), which designates the level of a contaminant in drinking water below which there is no known or expected risk to health.

Exceedances in any of the standards and worst case metals and acidity loading rates are discussed below by site. The tables present a comprehensive data summary of the detections per site. Sample results showing exceedances are summarized in **Figures 16 through 26**. **Table 22** presents a summary of general site conditions, discharge chemistry/loading rates of select metals of worst case sample result per site, and the relationship between pH and metals loading. The pH and metals data were used to prioritize the sites based on acidity and metals loading with the worst site ranked first and least contaminated last.

The following sections summarize the sample results by listing only metals and wet chemistry data that exceeded the applicable standards for each parameter. Poplar Spring is not discussed because no sampling was performed at the site in 2014.

4.1. Reference Samples

4.1.1 Surface Water Samples

Samples USFS-RC-40-051914, USFS-RC-22-052114, USFS-RC-20-052214, USFS-RC-42-052214, USFS-RC-47-052114, USFS-RC-51-052114, and USFS-RC-55-052114 exceeded the Kentucky Surface Water standard for **copper (**see **Tables 12a, 13b, 14b, 15a, and 16a)**. Additionally, samples USFS-RC-55-052114 and USFS-RC-20-052214 (see **Table 18a**) exceeded the USEPA standard for **manganese**, and samples Sample USFS-RC-51-052114 and USFS-RC-55-052114 exceeded the Kentucky Surface Water standard for **nickel**. Local reference standards were taken near the Cabin Branch, Jones Branch, Upper Rock Creek, and Roberts Hollow mine sites. Each standard was taken upstream of the associated mine feature.

4.1.2 Sediment Samples

Sample USFS-RC-55-052914 did not exceed any applicable criteria (see **Tables 13b, 14b, 15b, 16b, 17b, 18b, 19b, and 21b)**.

4.1.3 Pore-water (Groundwater) Quality

Sample USFS-BF1-070114 and sample USFS-BF2-070114 both exceeded the KY Surface Water standards for **pH**, **aluminum**, **iron**, and **manganese**. Sample USFS-BF1-070114 additionally exceeded the USEPA standards for **arsenic** and **lead (**see **Table 12c)**.

4.2. Cabin Branch and Unnamed Branch Mines

4.2.1 Surface Water Samples

Samples USFS-RC-36-051914, USFS-RC-37-051914, USFS-RC-38-051914, and USFS-RC-39-051914 exceeded the Kentucky Surface Water and/or USEPA standards for **pH**, **sulfate**, **aluminum**, **beryllium**, **iron**, and **manganese (**see **Table 12A** and **Figures 16A** & **16B)**. Samples USFS-RC-37-051914, USFS-RC-38-051914, and USFS-RC-39-051914 additionally exceeded those standards for **conductivity**, **chromium**, **copper**, **nickel**, and **zinc**, and samples USFS-RC-37-051914 and USFS-RC-39-051914 exceeded those standards for **cadmium**.

4.2.2 Sediment Samples

Sample USFS-RC-37-052814 exceeded the Residential Soil RML for **iron (**see **Table 12b)**.

4.2.3 Refuse Pile Toe Pore-water (Groundwater) Quality

No groundwater samples were taken near the Cabin Branch site.

4.2.4 Metals and Acidity Loading Rates

The Cabin Branch samples were combined with the Unnamed Branch samples for the loading rate calculations (see **Table 22**). The worst case sample point loading rates for the contaminants at Cabin Branch and Unnamed Branch were calculated as 4,725,497 milligrams per day (mg/day) for iron; 70,637 mg/day for manganese; 1,134,773 mg/day for aluminum; and 20,111,976 mg/day $CaCO_3$ in terms of acidity. The total worst case sample point metals loading for the site was calculated to be 5,930,907 mg/day. Based on both the calculated metals loading and the calculated acidity loading, the Cabin Branch and Unnamed Branch Mines site is ranked fourth among the Rock Creek sites.

4.2.5 Surface Water Samples

Sample USFS-RC-33-051914 exceeded the Kentucky Surface Water standard for **chromium (**see **Table 12a)**. Sample USFS-RC-34-052014 exceeded the Kentucky Surface Water and/or the USEPA standards for **pH**, **iron**, and **manganese** (see **Table 12A**).

4.2.6 Sediment Samples

Although sample USFS-RC-33-052814 exceeded many maximum local reference concentrations, it did not exceed any applicable criteria (see **Table 12b**).

4.2.7 Refuse Pile Toe Pore-water (Groundwater) Quality

No groundwater samples were taken near the Unnamed Branch site.

4.2.8 Metals and Acidity Loading Rates

The Unnamed Branch samples were combined with the Cabin Branch samples for the loading rate calculations. The worst case sample point loading rates for the contaminants at Cabin Branch and Unnamed Branch were calculated as 4,725,497 mg/day for iron; 70,637 mg/day for manganese; 1,134,773 mg/day for aluminum; and 20,111,976 mg/day $CaCO_3$ in terms of acidity. The total worst case sample point metals loading for the site was calculated to be 5,930,907 mg/day. Based on both the calculated metals loading and the calculated acidity loading, the Cabin Branch and Unnamed Branch Mines site is ranked fourth among the Rock Creek sites.

4.3. Big Momma Mine

4.3.1 Surface Water Samples

Samples USFS-RC-60-052014 and USFS-RC-61-052014 both exceeded the Kentucky Surface Water and/or the USEPA standards for **aluminum**, **iron**, and **manganese (**see **Table 13A** and **Figures 17A** & **17B)**. Sample USFS-RC-60-052014 also exceeded the standard for **sulfate**, and sample USFS-RC-61-052014's **pH** is outside of the KY Surface Water for Warm Water Aquatics standard range.

4.3.2 Sediment Samples

Sample USFS-RC-55-052914 exceeded the Residential Soil RMLs for **cobalt**, **iron**, and **manganese (**see **Table 13b)**.

4.3.3 Refuse Pile Toe Pore-water (Groundwater) Quality

No groundwater samples were collected near the Big Momma Mine site.

4.3.4 Metals and Acidity Loading Rates

The worst case sample point loading rates for the contaminants at the Big Momma Mine site were calculated as 5,559,408 mg/day for iron; 838,544 mg/day for manganese; 115,358 mg/day for aluminum; and 71,345,736 mg/day $CaCO_3$ in terms of acidity (see **Table 22**). The total worst case sample point metals loading for the site was calculated to be 6,513,310 mg/day. Based on both the calculated metals loading and the calculated acidity loading, the Big Momma Mine site is ranked third among the Rock Creek sites.

4.4. Cooperative South Mine

4.4.1 Surface Water Samples

Samples USFS-RC-28-052014, USFS-RC-29-052014, and USFS-RC-30-052014 exceeded the Kentucky Surface Water and/or the USEPA standards for **conductivity**, **iron**, and **manganese (**see **Table 14A** and **Figures 18A** & **18B)**. Samples USFS-RC-31-052014 and USFS-RC-58-052014 exceeded those standards for **aluminum** and **manganese**, while USFS-RC-31-052014 also exceeded the standards for **pH** and **iron**.

4.4.2 Sediment Samples

Although sample USFS-RC-58-052814 exceeded many maximum local reference concentrations, it did not exceed any applicable criteria (see **Table 14b**).

4.4.3 Refuse Pile Toe Pore-water (Groundwater) Quality

No groundwater samples were collected near the Cooperative South Mine site.

4.4.4 Metals and Acidity Loading Rates

The worst case sample point loading rates for the contaminants at the Cooperative South Mine site were calculated as 784,858 mg/day for iron; 32,702 mg/day for manganese; 2,722 mg/day for aluminum; and 13,407,984 mg/day $CaCO_3$ in terms of acidity (see **Table 22**). The total worst case sample point metals loading for the site was calculated to be 820,282 mg/day. Based on the calculated metals loading, the Cooperative South Mine is ranked seventh among the Rock Creek sites; however, based on the calculated acidity loading, the Cooperative South Mine site is ranked fifth among the Rock Creek sites.

4.5. Jones Branch Mine

4.5.1 Surface Water Samples

Samples USFS-RC-23-052114, USFS-RC-24-052114, USFS-RC-25-052114, and USFS-RC-26-052114 exceeded the Kentucky Surface Water and/or the USEPA standards for **pH**, **conductivity**, **sulfate**, **aluminum**, **beryllium**, **iron**, and **manganese (**see **Table 15A** and **Figures 19A** & **19B)**. Samples USFS-RC-23-052114, USFS-RC-24-052114, and USFS-RC-25-052114 also exceeded the standards for **cadmium** and **chromium**, and sample USFS-21-052114 exceeded the standards for **aluminum** and **manganese**. Sample USFS-RC-63-052114 exceeded the standards for **conductivity** and **aluminum**.

4.5.2 Sediment Samples

Although sample USFS-RC-63-052814 exceeded many maximum local reference concentrations, it did not exceed any applicable criteria (see **Table 15b**).

4.5.3 Coal Refuse Pile Pore-Water (Groundwater) Quality

Sample USFS-JB1-070114 exceeded the KY Surface Water for Warm Water Aquatics Standards' **pH** range (see **Table 15c**). The sample additionally exceeded the USEPA's Secondary Drinking Water Standard for **sulfate**, **aluminum**, **iron**, and **manganese**, and the most stringent of the USEPA's National Primary Drinking Water Regulations MCL and/or MCLG for **total dissolved solids** and **thallium**.

4.5.4 Metals and Acidity Loading Rates

The worst case sample point loading rates for the contaminants at the Jones Branch Mine site were calculated as 18,204,336 mg/day for iron; 235,457 mg/day for manganese; 3,608,165 mg/day for aluminum; and 72,272,304 mg/day $CaCO_3$ in terms of acidity (see **Table 22**). The total worst case sample point metals loading for the site was calculated to be 22,047,958 mg/day. Based on both the calculated metals loading and the calculated acidity loading, the Jones Branch Mine site is ranked second among the Rock Creek sites.

4.6. Upper Rock Creek Fidelity North Mine

4.6.1 Surface Water Samples

Samples USFS-RC-43-052214 and USFS-RC-44-052214 exceeded the Kentucky Surface Water standards for **pH**, and sample USFS-RC-45-052214 exceeded the Kentucky Surface Water and/or the USEPA standards for **conductivity**, **iron**, and **manganese (**see **Table 16A** and **Figures 20A** & **20B**).

4.6.2 Sediment Samples

No sediment samples were collected near Upper Rock Creek.

4.6.3 Coal Refuse Pile Pore-Water (Groundwater) Quality

No groundwater samples were collected near Upper Rock Creek.

4.6.4 Metals and Acidity Loading

The worst case sample point loading rates for the contaminants at the Upper Creek Fidelity North Mine site were calculated as 64,097 mg/day for iron; 6,540 mg/day for manganese; 363 mg/day for aluminum; and 1,242,691 mg/day $CaCO_3$ in terms of acidity (see **Table 22**). The total worst case sample point metals loading for the site was calculated to be 71,000 mg/day. Based on both the calculated metals loading and the calculated acidity loading, the Upper Creek Fidelity North Mine site is ranked eighth among the Rock Creek sites.

4.7. Paint Cliff Mine

4.7.1 Surface Water Samples

Samples USFS-RC-9-052214, USFS-RC-10-052214, USFS-RC-11-052214, USFS-RC-12-052214, USFS-RC-13-052214, USFS-RC-14-052214, USFS-RC-15-052214, USFS-RC-52-052214, and USFS-RC-53-052214 all exceeded the Kentucky Surface Water and/or the USEPA standards for **conductivity**, **sulfate**, **aluminum**, **iron**, **manganese**, and **nickel (**see **Table 17A** and **Figures 21A** & **21B)**. All of those samples except for USFS-RC-53-052214 also exceeded the KY Surface Water and the Warm Water Aquatic standard's **pH** range, and all of the above-listed samples except for USFS-RC-9-052214 exceeded the USEPA standard for **zinc**. Additionally, all of the surface water samples taken at the site except for USFS-RC-10-052214 exceeded the standards for **beryllium** and **chromium**. Lastly, samples USFS-RC-13-052214, USFS-RC-14-052214, USFS-RC-15-052214, and USFS-RC-52-052214 exceeded the State of Kentucky standard for **cadmium**.

4.7.2 Sediment Samples

Although samples USFS-RC-67-052714, USFS-RC-70-052714, USFS-RC-66-052714 exceeded many maximum local reference concentrations, no constituents exceeded any applicable criteria (see **Table 17B**).

4.7.3 Coal Refuse Pile Pore-Water (Groundwater) Quality

Both samples USFS-PC1-063014 and USFS-PC2-0063014 exceeded the KY Surface Water and the Warm Water Aquatic standards' range for **pH**, the EPA's Secondary Drinking Water Standard for **sulfate**, **aluminum**, **iron**, and **manganese**, and the EPA's National Primary Drinking Water Regulations MCL and/or MCLG for **total dissolved solids**, **arsenic**, **lead**, and **thallium (**see **Table 17C)**.

4.7.4 Metals and Acidity Loading

The worst case sample point loading rates for the contaminants at the Paint Cliff Mine site were calculated as 52,160,328 mg/day for iron; 1,945,793 mg/day for manganese; 6,605,885 mg/day for aluminum; and 154,682,352 mg/day $CaCO_3$ in terms of acidity (see **Table 22**). The total worst case sample point metals loading for the site was calculated to be 60,712,006 mg/day. Based on both the calculated metals loading and the calculated acidity loading, the Paint Cliff Mine site is ranked first among the Rock Creek sites.

4.8. Roberts Hollow Mine

4.8.1 Surface Water Samples

Samples USFS-RC-16-052214, USFS-RC-17-052214, USFS-RC-18-052214, USFS-RC-19-052214, and USFS-RC-54-052214 exceeded the Kentucky Surface Water and/or the USEPA standards for **conductivity**, **sulfate**, **aluminum**, **iron**, and **manganese (**see **Table 18A** and **Figures 22A** & **22B)**. Additionally, samples USFS-RC-16-052214, USFS-RC-18-052214, and USFS-RC-54-052214 exceeded those standards for **pH** and **beryllium**, and samples USFS-RC-16-052214 and USFS-RC-54-052214 exceeded those standards for **cadmium** and **nickel**.

4.8.2 Sediment Samples

Although sample USFS-RC-17-052914 exceeded many maximum local reference concentrations, it did not exceed any applicable criteria (see **Table 18B**).

4.8.3 Coal Refuse Pile Pore-Water (Groundwater) Quality

Samples USFS-ERH1-63014, USFS-ERH2-63014, and USFS-WRH1-070114 exceeded the Kentucky Surface Water and/or the USEPA standards for **aluminum**, **iron**, **manganese**, and **total dissolved solids**. Additionally, samples USFS-ERH1-63014 and USFS-WRH1-070114 exceeded the Kentucky Surface Water standard for **pH**, and sample USFS-ERH1-63014 exceeded the standards for **sulfate**, **arsenic**, and **thallium (**see **Table 18C)**.

4.8.4 Metals and Acidity Loading

The worst case sample point loading rates for the contaminants at the Roberts Hollow Mine site were calculated as 1,118,422 mg/day for iron; 68,839 mg/day for manganese; 629,521 mg/day for aluminum; and 7,766,820 mg/day $CaCO_3$ in terms of acidity (see **Table 22**). The total worst case sample point metals loading for the site was calculated to be 1,816,782 mg/day. Based on the calculated metals loading, the Roberts Hollow Mine is ranked sixth among the Rock Creek sites; however, based on the calculated acidity loading, the Roberts Hollow Mine site is ranked seventh among the Rock Creek sites.

4.9. Koger Fork Mine

4.9.1 Surface Water Samples

Samples USFS-RC-8-052814, USFS-RC-50-052814, USFS-RC-59-052814, USFS-RC-7-052814, and USFS-RC-56-052814 exceeded the applicable Kentucky Surface Water and USEPA standards for **aluminum** and **manganese** (see **Table 19A** and **Figures 24A** & **24B**). Samples USFS-RC-59-052814, USFS-RC-7-052814, and USFS-RC-56-052814 also exceeded those standards for **pH**, **sulfate**, **cadmium**, and **nickel**. Samples USFS-RC-7-052814 and USFS-RC-56-052814 exceeded the standards for **conductivity**, **beryllium**, **copper**, and **zinc**; and those two samples and USFS-RC-8-052814 exceeded the standards for **chromium**. The State of Kentucky standard for **iron** was exceeded by all of the samples except for USFS-RC-59-052814, and the Kentucky standard for **lead** was exceeded only by sample USFS-RC-8-052814.

4.9.2 Sediment Samples

Although sample USFS-RC-50-052814 exceeded many maximum local reference concentrations, it did not exceed any applicable criteria (see **Table 19B**).

4.9.3 Coal Refuse Pile Pore-Water (Groundwater) Quality

No groundwater samples were collected near Koger Fork.

4.9.4 Metals and Acidity Loading

The worst case sample point loading rates for the contaminants at the Koger Fork Mine site were calculated as 1,095,530 mg/day for iron; 523,783 mg/day for manganese; 773,957 mg/day for aluminum; and 9,102,168 mg/day $CaCO_3$ in terms of acidity (see **Table 22**). The total worst case sample point metals loading for the site was calculated to be 2,393,271 mg/day. Based on the calculated metals loading, the Koger Fork Mine is ranked fifth among the Rock Creek sites; however, based on the calculated acidity loading, the Koger Fork Mine site is ranked sixth among the Rock Creek sites.

4.10. Water Tank Hollow Mine

4.10.1 Surface Water Samples

No surface water samples were collected near Water Tank Hollow.

4.10.2 Sediment Samples

No sediment samples were collected near Water Tank Hollow.

4.10.3 Coal Refuse Pile Pore-Water (Groundwater) Quality

Sample USFS-WT1-070214 exceeded the USEPA's Secondary Drinking Water Standard for **sulfate**, **aluminum**, **iron**, and **manganese (**see **Table 20** and **Figures 25A** & **25B)**. Additionally, the sample exceeded the most stringent of the USEPA's National Primary Drinking Water Regulations MCL and/or MCLG for **total dissolved solids**, **arsenic**, **lead**, and **thallium**.

4.10.4 Metals and Acidity Loading

The worst case sample point loading rates for the contaminants at the Water Tank Hollow Mine site were calculated as 31,885 mg/day for iron; 2,992 mg/day for manganese; 5,992 mg/day for aluminum; and 327,024 mg/day $CaCO_3$ in terms of acidity (see **Table 22**). The total worst case sample point metals loading for the site was calculated to be 40,469 mg/day. Based on both the calculated metals loading and the calculated acidity loading, the Water Tank Hollow Mine site is ranked tenth among the Rock Creek sites.

4.11. Grassy Fork Mine

4.11.1 Surface Water Samples

Samples USFS-RC-1-052914, USFS-RC-2-052914, USFS-RC-3-052914, USFS-RC-5-052914, and USFS-RC-6-052914 all exceeded the applicable Kentucky Surface Water and/or the USEPA standards for **pH** (see **Table 21A** and **Figures 26A** & **26B**). Additionally, samples USFS-RC-1-052914, USFS-RC-2-052914, and USFS-RC-3-052914 exceeded the standards for **aluminum** and **manganese**, and sample USFS-RC-1-052914 exceeded the Kentucky Surface Water standard for **chromium**. Lastly, sample USFS-RC-3-052914 exceeded the Kentucky Surface Water standard for **copper**, **iron**, and **nickel**.

4.11.2 Sediment Samples

Although sample USFS-RC-6-052914 exceeded many maximum local reference concentrations, it did not exceed any applicable criteria (see **Table 21B**).

4.11.3 Refuse Pile Toe Pore-water (Groundwater) Quality

No groundwater samples were collected near the Grassy Fork Mine site.

4.11.4 Metals and Acidity Loading Rates

The worst case sample point loading rates for the contaminants at the Grassy Fork Mine site were calculated as 6,377 mg/day for iron; 1,924 mg/day for manganese; 12,536 mg/day for aluminum; and 457,834 mg/day $CaCO_3$ in terms of acidity (see **Table 22**). The total worst case sample point metals loading for the site was calculated to be 20,837 mg/day. Based on both the calculated metals loading and the calculated acidity loading, the Grassy Fork Mine site is ranked ninth among the Rock Creek sites.

4.12. Summary of Rock Creek Abandoned Mine Sites Requiring Response Action

Concentrations exceeding the applicable standards generally indicate a potential risk to human and/or ecological receptors at the site. Several contaminants had concentrations exceeding screening criteria and were identified as Contaminants of Concern (COCs). The highest concentrations appeared to be in surface water and sediment at select locations, particularly areas receiving AMD from underground mine workings through the adits. The source, nature, and extent of contamination at the site have been described in the preceding paragraphs by media type. A snapshot of COCs identified per site include a few or combination of metals such as aluminum, arsenic, beryllium, cadmium, chromium, cobalt, copper, iron, lead, manganese, nickel, thallium, and zinc.

Site ranking was assessed based on acidity and metals loading. The purpose of the ranking was to prioritize the relative impacts associated with AMD at the Rock Creek abandoned mine sites and provide a mechanism for prioritizing removal actions with the high priority sites placed at the top. The ranking is as follows:

Based on Acidity Loading

1) Paint Cliff
2) Jones Branch
3) Big Momma
4) Cabin Branch
5) Cooperative South
6) Koger Fork
7) Roberts Hollow
8) Upper Rock Creek Fidelity North
9) Grassy Fork
10) Water Tank Hollow

Based on Metals Loading

1) Paint Cliff
2) Jones Branch
3) Big Momma
4) Cabin Branch
5) Koger Fork
6) Roberts Hollow
7) Cooperative South
8) Upper Rock Creek Fidelity North
9) Grassy Fork
10) Water Tank Hollow

4.13. Physical Hazards Associated with Rock Creek Abandoned Mine Sites

Physical hazards at the sites consist primarily of open and/or collapsed adits, mine subsidence, steep slopes, and soft ground around wet areas. The adits are located some distance away from access roads and at a few sites do not appear to be accessible without significant effort. The subsidence observed at some of the sites is relatively shallow depressions in the ground surface and do not pose a significant fall hazard.

Physical hazards may be mitigated through institutional controls such as fencing, gating and/or signs, which limit public access, or by removal of the hazard, e.g., plugging with foam or filling the hazard. Recommended mitigation measures include clearing soil and rock from the opening and installing a bat gate or culvert to prevent public access while maintaining potential bat habitat.

5. ROCK CREEK ABANDONED MINE SITES CLEANUP CRITERIA

Cleanup criteria are based on Applicable or Relevant and Appropriate Requirements (ARARs). ARARs are "applicable" or "relevant and appropriate" federal and state environmental requirements. Applicable requirements include cleanup standards and other substantive requirements, criteria, or limitations promulgated under federal or state laws that apply to hazardous substances and removal actions at the site. Relevant and appropriate requirements are not applicable to the site but may be suitable for use as they address issues or problems sufficiently similar to those present at the site. In addition to ARARs, federal and state environmental and public health guidance and proposed standards that are not legally binding but may prove useful are "to be considered" (TBC) standards.

5.1. Applicable or Relevant and Appropriate Requirements

Throughout any remedial or removal action undertaken pursuant to CERCLA at an abandoned mining and mineral-processing site, the project plan must consider compliance with CERCLA ARARs. Although Section 121 of CERCLA does not require that removal actions attain all ARARs and TBCs, the USEPA policy on removal actions is that ARARs and TBCs will be identified, considered, and attained to the extent practicable. USDA FS will comply with this policy.

The ARARs and TBCs for the proposed actions for the Rock Creek abandoned mine sites are listed in **Appendix D**. These potential ARARs and TBCs are categorized into the following USEPA recommended classifications:

- Chemical-specific ARARs and TBCs;
- Location-specific ARARs and TBCs; and,
- Action-specific ARARs and TBCs.

A discussion of each group and its relationship to the proposed action is given below.

5.1.1 Chemical-Specific ARARs and TBCs

Chemical-specific ARARs set health or environmental risk-based concentration or discharge limits in various environmental media for specific hazardous substances, pollutants, or contaminants. TBCs are non-promulgated advisories, proposed rules, criteria, or guidance documents issued by federal or state government that are not legally binding and do not have the status of potential ARARs; however, these items are to be considered when determining protective cleanup levels where no ARAR exists, or where ARARs are not sufficiently protective of human health and the environment. These requirements generally set protective cleanup levels for the chemicals of concern in the designated media or indicate a safe level of discharge that may be incorporated when considering a specific remedial activity.

The chemical-specific ARARs and TBCs apply to all of the proposed removal actions since the contaminant concentration drives the action level for the implementation of the removal action. The chemical-specific ARARs and TBCs identified for the Rock Creek abandoned mine sites pertain to acid (H^+ ions) and pH and are derived from the Clean Water Act (Water Quality Standards). The chemical-specific ARARs and TBCs, which provide protection from chemical constituents in surface water and groundwater, are used as the basis for the public health and environmental risk evaluation for each alternative. Standards evaluated include the following:

- State of Kentucky Water Quality Standards for Surface Water (Chapter 401 Kentucky Administrative Regulations [KAR] 10:031)
- State of Kentucky Drinking Water Standards (Chapter 401 KAR 47:030)
- Federal Water Quality Criteria for Surface Water (40 CFR 131.26)
- National Toxics Rule Water Quality Standards (40 CFR 131.26)
- USEPA National Secondary Drinking Water Regulations and Maximum Contaminant Levels
- USEPA Region 4 Ecological Risk Assessment Fresh Water Surface Water Screening Values

5.1.2 Location-Specific ARARs and TBCs

Location-specific ARARs set restrictions on the concentration of hazardous substances or the conduct of activities solely as they are in special locations. For example, location-specific ARARs will take into consideration the existence of wetlands or floodplain areas, the presence of threatened and endangered species, and cultural and historical resources (e.g., areas of historical significance) that may exist in or be a part of the project site. When an alternative is chosen for a particular mine area, the affected location will be surveyed to determine if any of the location-specific ARARs or TBCs will be applicable.

5.1.3 Action-Specific ARARs and TBCs

Action-specific ARARs and TBCs include technology- or activity-based requirements of, or limitations on, actions taken with respect to the COCs and potential COCs. These requirements are triggered by the specific remedial activities selected to accomplish a remedy. Action-specific requirements do not in themselves determine the remedial alternative; rather, they indicate how a selected alternative must be achieved (e.g., land disposal restrictions). Action-specific ARARs specify particular performance standards or technologies, as well as environmental levels for discharged or residual chemicals. All alternatives for removal action involve on-site construction and/or excavation activities necessary to implement the action. Consideration must be given to fugitive dust emissions, erosion potential from the operation of heavy equipment, and the effects of such activities on the quantity and quality of stormwater discharges. Implementation of good site planning and best management practices to control any stormwater discharges and sedimentation is required.

Site-specific tables list the ARARs and TBCs that will be considered by the USDA FS for the various alternative actions proposed in this EE/CA. ARAR-based cleanup goals for the Rock Creek Site are limited to surface water, pore water, and sediment since no contaminant-specific ARARs exist for mine refuse/waste. ARARs for surface water, pore water, and sediment are discussed below. The groundwater pathway is potentially complete at a number of the sites; however, the significance could not be determined since no groundwater investigation was performed for this EE/CA.

5.2. STREAMLINED RISK EVALUATION

This section identifies the hazards that the contaminants from the Rock Creek abandoned mine sites present to the public health, welfare and the environment based on criteria established by federal regulations and USDA FS guidelines. A conceptual site model based on the potential contaminant migration pathways is also described. Streamlined human health and ecological risk assessments were evaluated to assess potential risks to human health and ecological receptors from exposure to mine waste, sediment, and surface water at the site. Analytical data and other information presented in the PA/SI reports and the 2014 sampling were evaluated based on risk-based cleanup criteria set by the state and/or federal regulations and guidelines.

5.2.1 Hazards of the Contamination

The USDA FS has determined that conditions at the Rock Creek abandoned mine sites represent a threat to public health, welfare or the environment as defined under both Section I of the USDA FS Guide to CERCLA (USDA 1996) and Section 300.415(b)(2) of the National Contingency Plan (NCP). The following criteria are the basis for this determination.

1. Actual or potential exposure to nearby human populations, animals, or the food chain from hazardous substances or pollutants or contaminants.

The resultant low pH and elevated metals concentrations have rendered the water seeping either directly or via streams into White Oak and/or Rock Creek unfit for drinking water usage, the sustainability of a viable fish and other aquatic species populations, and primary and secondary recreation. Recent fish and macroinvertebrate inventories have produced scientific evidence that supports this assessment. Rock Creek between its confluence with White Oak Creek and its discharge into the Big South Fork of the Cumberland River has been heavily impacted by AMD. The AMD originates primarily from the abandoned mine complexes and coal waste piles at Cabin Branch, Jones Branch, Paint Cliff/Mine 16 Complex, and Poplar Spring Hollow. Low pH (2-3), high concentrations of iron, other metals, and sulfates characterize streams in the affected area. Typical aquatic life, including popular game fish, has been historically absent from this reach and its tributaries; however, beginning in 1996, the Rock Creek Task Force, through cooperative venturing among ten state and federal agencies and Trout Unlimited, have worked to improve the water quality in the lower 4 miles of Rock Creek.

Human Exposure Assessment

An exposure assessment identifies potentially exposed human populations, exposure pathways, and typical exposure durations. Analytical results for AMD samples are used to estimate COC concentrations at exposure points and the potential intake of contaminants. Except for the private residences close to some of the sites, there is no residential use of National Forest Ranger District property in or around any of the discharges considered in this EE/CA. The highest potential for human exposure to site-related contaminants in AMD is via seasonal recreational activities that occur during the snow-free period in the District, which generally falls between the months of March and October.

Ecological Exposure Assessment

Two groups of ecological receptors have been identified as potentially being affected by site contamination. The first group includes aquatic life residing in streams downstream of where discharges enter a surface water course. This population may be affected by concentrations of COCs that directly enter the receiving stream. The second group of receptors is wildlife that may utilize the discharge water for consumption.

Potentially adverse exposures of elevated metals to aquatic life and wildlife can be quasi-quantitatively assessed by comparing site-specific water quality criteria to toxicity-based criteria and standards. Exposure pathways for aquatic life include: 1) direct exposure of aquatic organisms to metals in surface water that exceed toxicity thresholds; and 2) ingestion of aquatic species (e.g., insects) that have accumulated contaminants by predators to the extent that they are toxic to predators (e.g., fish).

Exposure pathways for wildlife include direct contact (dermal exposure) with discharge water and ingestion of discharge water. Instances of direct contact might occur from wading or swimming through discharges. Ingestion would likely occur from incidental ingestion rather than purposeful drinking, since most of the discharges would likely be avoided in preference to other easily obtainable sources of water, as the odor, sight and taste attributes of adit discharges are likely less desirable.

Exposure pathways for aquatic species apply only for those AMDs that reach a surface water body where aquatic species reside. All of the Rock Creek abandoned mine sites discharges flow into tributaries to White Oak Creek or Rock Creek. Exposure pathways for wildlife are likely, as wildlife may tend to wade into the affected tributaries; however, exposure to discharge waters on any day is thought to likely be of very short duration.

2. Actual or potential contamination of drinking water supplies or sensitive ecosystems.

Since the Rock Creek abandoned mine sites lie within a rural, forested area of low-density population, the traditional source of drinking water for nearby residents has been from private domestic groundwater wells. Currently, there are no known drinking water sources that rely on groundwater in the immediate downgradient vicinity of the AMD sources; however, AMD water that enters into the nearby karst terrain creates the potential for pollution of the underlying aquifer. Groundwater can travel rapidly through underground karst conduits (up to several miles a day) and contaminants can be transmitted quickly to wells and springs in the vicinity. There is one known domestic well within the vicinity of the Jones Branch site.

The Nature Conservancy classifies White Oak and Rock Creek as a "Critical Watersheds" to conserve at-risk fish and mussel species. These aquatic species, and others, require a moderate pH range of 6.0 to 9.0 and can tolerate only a minimal amount of metals loading, a loading that is consistently exceeded by water in these creeks.

3. Weather conditions that may cause hazardous substances of pollutants or contaminants to migrate or be released.

The Rock Creek abandoned mine sites receive an annual rainfall of nearly 50 inches, 15 of which is snowfall. This high volume rainfall coupled with moderate to steep slope gradients produces increased underground and overland wet weather flow that can cause contaminants and pollutants to be transported and released off site. Pyritic materials in exposed spoils and coal waste piles are also oxidized and mobilized as acidic runoff.

5.2.2 Contaminant Migration Pathways

The PA/SIs and APAs already completed for the Sites (USDA 2009, USDA 2010, and USDA 2013) concluded that releases of hazardous substances, pollutants, and/or contaminants have occurred along the surface water, sediment, and soil exposure pathways and that the potential of a release exists for the groundwater pathway. These releases are expected from both base-flow (dry-weather) and wet-weather flows of AMD from the sites within the watersheds. This section presents, in narrative form, a conceptual site model that identifies both human and biotic receptors, and primary and secondary release mechanisms.

5.2.2.1 Groundwater Pathway

Groundwater conditions at the Rock Creek abandoned mine sites are not well documented, and no groundwater samples were collected during the PA/SI stages or the additional sampling performed in 2014 by the USDA. With the exception of Jones Branch, there are no domestic groundwater wells located within the Rock Creek abandoned mine sites, and future use (including the Jones Branch well) as a drinking water source is not anticipated; therefore, treatment of groundwater (beyond the mine pools) is outside the scope of these removal actions. The Jones Branch well (a domestic well, with an ID of AKGWA 0044900) was completed in 1998 at a depth of 97 feet. Static water level is generally measured at 28 feet below ground surface. This suggests the groundwater ingestion exposure pathway is potentially complete; however, the significance could not be determined due to the lack of groundwater quality data. If contamination of domestic groundwater is discovered in the future, additional sampling and analysis will need to be completed, and a separate removal/remedial process will need to be initiated.

There are approximately 16 known domestic wells within a 4-mile radius of the confluence of White Oak Creek with Rock Creek (Kentucky Geologic Map Service 2016). The only testing requirement for private groundwater systems in Kentucky is a bacteria test that must be completed when a well is initially installed (401 KAR 6:310). The McCreary County Health Department also tests wells upon request. Where contaminants in private water systems are found to be in excess of safe drinking water standards, water treatment may be used to reduce contaminant levels.

The groundwater pathway should be considered potentially threatened by the source waste materials at the Rock Creek abandoned mine sites for the following reasons:

- The high annual precipitation, the highly permeable nature of the soils, the presence of karst topography, and the unlined coal waste piles at Jones Branch, Cabin Branch, Cooperative South, Roberts Hollow, Paint Cliff, Koger Fork, and Grassy Fork allow for a high degree of infiltration of precipitation into the waste piles carrying with it AMD contaminants and low pH water. Ultimately, if the acidic and heavy metal-laden water does not exit near the waste pile and become seepage (or surface) water, it can recharge the groundwater.
- Affected water in the underground mine tunnels enters as groundwater through cracks and fissures in the underlying and/or surrounding rock. AMD can be released either via the subsurface or as a seep/flow out of the mine, and if it exits to the ground surface, eventually it can flow into the surface streams.
- The pyritic nature of the coal waste promotes high acidity (low pH) and, consequently, high dissolution and mobility of metals in the resultant drainage.

5.2.2.2. Surface Water Pathway

AMD enters local streams from seeps emanating from coal waste and spoil piles, and flows from mine portals. In addition, contaminated groundwater can discharge into the streams at some distance from the AMD source.

The Rock Creek abandoned mine sites are located off perennial streams, which are swift-flowing mountain streams that collect water from timbered basins before discharging into either White Oak Creek (Cabin Branch, Cooperative, and Jones Branch) or Rock Creek (Roberts Hollow, Paint Cliff, Poplar Spring, Koger

Fork, and Grassy Fork). These streams are 3rd-order streams that receive water from groundwater recharge during dry periods. The stream channels are, in large part, bedrock-controlled channels whose form is predominantly shaped by the local geology and only slightly by stream flow. Basin shape – typically rounded in this watershed – directly affects the storm hydrograph for this area and will have implications for the design of hydrologic structures. Under normal circumstances, these streams do not degrade very quickly and aggrade with sediment buildup only for short periods of time. The banks tend to be vertical with undercuts in some areas.

The Rock Creek watershed is one of the areas within the Commonwealth of Kentucky most heavily impacted by AMD. The watershed is about 37,000 acres in size, of which 24,000 acres is federally-owned surface under National Forest system management. Surface water flow in such steep terrain moves quickly to small rivulets or streams that feed into either stream's main channel. Drainage produced as leachate from coal waste and spoil piles from each source area is, therefore, only minutes away from probable point of entry into the nearest 2nd- or 3rd-order stream channel. Although the 100-year floodplain is narrowed by steep gradients along the stream channels, most of the mine areas lie within or drain directly into the floodplain (USDA 2004). Such a hydrologic setting increases the likely transport of contaminants during a high-precipitation event. The low pH and elevated concentrations of heavy metals have made the water reaching White Oak Creek and Rock Creek either directly or via tributaries, unfit for drinking water usage and unsuitable for the sustainability of a viable fish and other aquatic species populations. Recent fish and macroinvertebrate inventories have produced evidence that supports this assessment (USDA 2004). Ideal water quality habitat that is found in unaffected reaches in the vicinity of the site (such as along Cane Creek to the northeast of this region) sustains high populations of both fish and macroinvertebrates, such as mayflies, stoneflies, crayfish, caddis flies, and beetles, while the affected sections of White Oak and Rock Creek support very few species and individuals. Some sections of stream within the Rock Creek sites are completely devoid of aquatic life. Periodic fish kills have impacted the fishery, causing lost recreational opportunity, affecting the local economy. In addition, this area has been placed on Kentucky's 2004 303(d) List of Waters due to low pH and elevated metals.

Another possible surface water target is the few riparian wetlands located along Rock Creek and one found on Big South Fork just north of Yamacraw. These wetlands are all primary targets and are within a 15-mile downstream distance of the probable point of entry from the Rock Creek abandoned mine sites. These wetlands are a palustrine system with a forested subsystem and broad-leafed deciduous tree coverage. They are typically diked or impounded by a man-made barrier and may be flooded temporarily or seasonally with shallow water depths. The other is the Cumberland River basin itself, which has been classified as lacustrine system wetlands with a limnetic (deep-water habitats) subsystem and permanently-flooded, unconsolidated bottoms.

The surface water pathway must be considered threatened and already severely impacted by the source waste materials at the Rock Creek abandoned mine sites for the following reasons:

- The high annual precipitation at the site (averaging nearly 50 inches per year) allows for a high level of contaminant transport and associated groundwater recharge from precipitation directly through the unlined coal waste piles.
- The uncapped and unlined nature of the coal waste piles allows for hydraulic transmissivity through and across the waste and into adjacent streams and aquifers.

- Data resulting from several surface water studies in the proximity of coal waste areas have consistently shown very low pH and high concentrations of sulfate, metals, and total dissolved solids commonly associated with AMD. All such levels represent exceedances of applicable surface water quality standards and/or warm water aquatic habitat criteria.
- A reduction in fish and macroinvertebrate populations in waterways receiving AMD demonstrates the negative effects on natural stream chemistry.

A screening-level human health risk assessment has been completed for use in making risk management decisions on the path forward for the ten sites. The surface water and seep water ARARs are based on State of Kentucky and federal standards for the protection of aquatic life and human health. Surface water and seep water ARARs for metals were exceeded at a number of sites. Screening results of analytical data for surface water and push point pore-water samples are presented in **Tables 12** through **21**, respectively. In addition, a comparison of chemical data to human health screening levels has been performed.

The sediment ARARs are based on USEPA Region 4's May 2014 RML standards for the protection of human health and the environment. The pore water ARARs are based on State of Kentucky and federal standards for the protection of aquatic life and are listed as ecological screening criteria.

5.2.2.3. Soil Exposure Pathway

Evaluation of risk from the soil pathway considers the likelihood of soil ingestion, dermal contact, and transport of contaminants via water flowing through the soils. Pyritic and metallic materials contained in loose coal refuse and waste piles must be considered as a potential source. The runoff and leachate from coal waste and spoil piles contribute to the risks associated with the surface water and groundwater pathways.

Soils in the Rock Creek abandoned mine sites vary according to elevation due to their relationship to the various relatively horizontal geologic formations. Other influencing factors on the soil include disturbance, vegetation, aspect, and landform. The soil texture ranges from sandy to clay loams, depending on the underlying geology. Soil depth ranges from 0 feet to 8 feet. Most stream-level soil series include either Tate stony sandy loam or Tate-Trappist stony complex with a 30 to 50 percent slope. As hillsides rise from streams, the soils grade to Dekalb and Tate silt loams, with the highest elevation soils being Muse-Trappist silt loam.

The Tate series includes deep soils that are well-drained. It is the most extensive soil in the area and is formed on colluvium, which moved down slope from weathered sandstone and shale bedrock. Tate soils have a high moisture capacity, naturally low pH, and moderate fertility. The Dekalb soil series occupy the steeply sloping areas. Formed in the residuum that weathered in place from acidic sandstone, these soils tend to be moderately deep and excessively drained.

Vegetation throughout the region is primarily of mixed deciduous and coniferous forests with a diversity of plant communities in the understory. The coal waste piles primarily support growths of Virginia and short leaf pine trees. However, some older coal waste piles, such as those at Cooperative, support a diverse and mesic community, including yellow buckeye, pawpaw, and American beech. The difference may be due to compaction and age. Black locust trees were planted in years past, but their longevity was shortened to about 20 years, perhaps due to limited nutrient uptake from the coal waste piles.

Targeted populations for the soil pathway are primarily residents and workers within nearby areas. No on-site workers or residents are within 200 feet of the coal waste piles at the Rock Creek abandoned mine sites, nor are there any schools or day care centers within the same radius. The only potential on-site populations are recreational users, such as hikers, hunters, and fishermen, who are typically of adult age and are not at high risk from the waste piles.

According to U.S. census data, the following is a breakdown of the approximate number of persons living within a 4-mile and a half-mile radius of six of the Rock Creek abandoned mine sites, respectively:

- Cabin Branch: 708 and 115 persons;
- Big Momma: 3,212 and 14 persons;
- Jones Branch: 1,007 and no one living within 0.5 mile;
- Paint Cliff: 1,327 and 48 persons;
- Poplar Spring: 1,993 and no one living within 0.5 mile; and,
- Grassy Fork: 3,212 and 14 persons.

One Endangered Species, the Indiana myotis bat, has been identified in the area of Jones Branch (USDA 2004), and several other threatened or endangered species could potentially be in the area, including the Northern Long-eared bat, the Gray Bat, and the Virginia Big-eared bat.

The Rock Creek abandoned mine sites pose environmental hazards due to the soil pathway. Though the coal waste piles have been stabilized sufficiently due to age, geology, and vegetative cover that movement of soil itself and risk of dermal contact are minimal, the erosion of coal waste pile materials and water flowing through these piles can easily transport contaminants off site and contribute to the hazards posed by the surface water and groundwater pathways.

5.2.2.4. Air Exposure Pathway

Evaluation of risk from the air pathway considers the likelihood of soil disturbance that might release fugitive air emissions. The Rock Creek abandoned mine sites pose few environmental hazards due to the air pathway. The coal waste piles have been stabilized sufficiently due to age, geology, and vegetative cover and the dispersion of fugitive waste dust has not been a problem and is not anticipated to be one in the future.

Targeted populations for the air pathway are primarily residents and workers within nearby areas. There are no on-site workers or residents within 200 feet of the coal waste piles, nor are there any schools or day care centers within the same radius. Potential on-site populations include recreational users, such as hikers, hunters, and fishermen, and off highway vehicle (OHV) riders. Occasionally, Forest Service workers, particularly firefighters, are also active within the Rock Creek abandoned mines site boundaries. Prescribed burns have been conducted and planned in the area, and the Forest Service fire management personnel have been notified about the locations of the piles and advised to avoid them.

The primary risk to air exposure may be from OHV use on the soils associated with coal mines. These previously underground and surface mined areas at the Rock Creek abandoned mine sites are highly used areas by OHV users; OHV use is prohibited in many of these areas in the Forest, but illegal use remains a problem. The undergrowth and ground cover are rapidly being destroyed and removed by frequent trail use in these areas, and dust then becomes a problem. These dust plumes can carry toxic metals through the air, and inhalation of the dust by the OHV users, especially during dry periods, is most likely the result.

6. IDENTIFICATION OF REMOVAL ACTION OBJECTIVES AND SCHEDULES

Environmental risks associated with these discharges appear in surface water tributaries that receive the discharges. Contaminants (aluminum, beryllium, cadmium, chromium, arsenic, copper, manganese, nickel, iron, lead, thallium, and zinc) present ecological risks to aquatic life from ingestion and direct contact. In addition, wildlife species may be at risk from these discharges, although a detailed exposure assessment and risk characterization was not performed.

6.1. Removal Action Objectives

The following Removal Action Objectives (RAOs) are identified for the removal action:

- Reduce the releases and migration of COCs from the sites that currently result in exceedances of MCLs in groundwater and water quality criteria in surface water.
- Reduce releases and migration of COCs from the sites that result in unacceptable risks to wildlife receptors of concern due to elevated concentrations in soils, sediment, and fish in White Oak Creek and Rock Creek sub-basin.
- Reduce risks to livestock and humans due to exposure to COCs in surface water and sediments.
- Reduce concentrations of COCs in refuse pile pore water that may be migrating into surface water bodies.

By addressing the RAOs, releases and migration of COCs to the environment will be reduced. The removal action alternative will be selected to address these RAOs and to meet the ARARs. As will be discussed in **Section 8.0**, all removal action alternatives being considered for the AMD control in the Rock Creek abandoned mine sites would satisfy these objectives to varying degrees; however, due to the complex nature of the sites, no alternative will fully satisfy all of these objectives at each site area. The final selection of the recommended removal action would, therefore, balance the effectiveness of each alternative in satisfying these objectives against other decision factors judged to be of particular importance for the problem-specific and area-specific conditions.

6.2. Removal Action Justification/Rationale

Site data compiled to date indicate that coal refuse piles, collapsed/partially collapsed adits, AMD, and impacted surface water bodies pose potential risk to human health and the environment, and therefore qualify for response actions under 40 CFR 300.415 of the NCP. According to 40 CFR 300.415(b)(2) of the NCP, the appropriateness of a removal action can be determined by one or more of the following factors:

1. Actual or potential exposure of nearby human populations, animals, or food chain to hazardous substances, pollutants, or contaminants;
2. Actual or potential contamination of drinking water supplies or sensitive ecosystems;
3. Hazardous substances, pollutants, or contaminants in drums, barrels, tanks, or other bulk storage containers that may pose a threat of release;
4. High levels of hazardous substances, pollutants, or contaminants in soils largely at or near the surface with the potential for migration;

5. Weather conditions that may cause hazardous substances, pollutants, or contaminants to migrate or be released;
6. Threat of fire or explosion;
7. The availability of other appropriate federal or state response mechanisms to respond to the release; and/or
8. Other situations or factors that may pose threats to public health or welfare or the environment.

The appropriateness of and rationale for mine waste removal actions in the Rock Creek abandoned mine sites are related primarily to items 1, 2, 4, 5, and 6 above; and further discussed below referencing applicable site-specific conditions.

Factor	**Applicable Site Conditions**	**Removal Action Justified - Based on this Factor?**
(1) Actual or potential exposure to nearby human populations, animals, or the food chain from hazardous substances, pollutants, or contaminants.	Public access to coal refuse pile, sediment, and surface water containing high concentrations of metals and exposure to food chain.	**Yes**
(2) Actual or potential contamination of drinking water supplies or sensitive ecosystems.	No public water supply but ponds are drinking source for wildlife and sensitive species may inhabit the sites; karst topography and geology are present; emergent wetlands are present; high metals concentrations in surface water leaving the sites and contributing to downstream degradation.	**Yes**
(3) Hazardous substances, pollutants, or contaminants in drums, barrels, tanks, or other bulk storage containers that may pose a threat of release.	No drums, barrels, tanks, or bulk storage containers on site.	No
(4) High levels of hazardous substances, pollutants, or contaminants in soils largely at, or near, the surface that may migrate.	High concentrations of metals in coal refuse piles subject to erosion and migration.	**Yes**
(5) Weather conditions that may cause hazardous substances, pollutants, or contaminants to migrate or be released.	Coal refuse piles in a stream channel and subject to erosion during high flows, rain events, and snowmelt.	**Yes**

(6) Threat of fire or explosion.	Potential for long-term fire from ignition of coal refuse.	**Yes**
(7) The availability of other appropriate federal or state response mechanisms to respond to the release.	None	No
(8) Other situations or factors that may pose threats to public health or the environment.	None	No

6.3. Scope and Purpose

The scope of proposed removal actions can be broadly defined as reducing or eliminating the release of AMD and its contaminants of concern from the Rock Creek abandoned mine sites through treatment and control. Although there are a number of sites with coal refuse piles, no source removal was proposed in this EE/CA as it was determined that any attempt to implement an excavation and/or remining effort at these locations would result in compounding the AMD problem. As discussed in **Section 5.0**, contaminants of concern are low pH; elevated concentrations of aluminum, iron, manganese, and other metals; and elevated sulfate, a necessary component of resulting acidity. In addition, the removal action should decrease or eliminate the accumulation of iron hydroxide (“yellow boy”) on the stream bottoms. It is anticipated that multiple removal actions will be completed in a phased approach over several years. Selected removal actions will have varying degrees (years to decades) of operation and maintenance, in addition to long-term monitoring for effectiveness.

6.4. Removal Action Schedule

The general schedule for removal activities, including both the start and completion time for the non-time-critical removal actions, should be part of the EE/CA (USEPA 1993). Although EE/CAs are only required when a planning period of at least six (6) months is available, the nature of the threat may still dictate that action be initiated within 12 months or some other specific time period. The start dates may also be influenced by weather conditions, planning, survey, design needs, availability of supplies and materials, and funding availability. In view of these uncertain variables, it is difficult to estimate a start date for the selected removal actions.

The completion time is also influenced by such factors as the nature of the threat, the time frame to ensure adequate protection of public health and the environment, the type of removal action, weather, and availability and statutory limits of funding. Again, it is difficult to estimate a completion time in view of the uncertain nature of these factors. For purposes of cost estimating, project duration is assumed to be five (5) years from the start date for each alternative selected, in addition to operation, maintenance, and costs, where applicable.

7. IDENTIFICATION AND ANALYSIS OF MANAGEMENT AND REMOVAL ACTION ALTERNATIVES

This section identifies potential removal action technologies and alternatives applicable to each of the sites and screens to eliminate ineffective or unfeasible alternatives; and, analyze selected removal action alternatives based on effectiveness, implementability, and cost.

7.1. Technology Identification and Screening

Removal action technologies applicable to the sites were identified based on a review of technical literature and previous experience at similar mine sites. A set of potential removal action alternatives was initially screened using a predefined set of criteria consistent with USEPA guidance on conducting an EE/CA. The technologies were screened to eliminate inappropriate, ineffective, infeasible, or cost prohibitive methods. A smaller set of alternatives resulting from the initial screening were evaluated using professional engineering judgment based upon the criteria of effectiveness, implementability, cost, and compliance with site-specific ARARs to the extent practicable. The alternatives will be removal actions to remove, treat, or control either the contaminated water or the source material that produces the contaminated water.

Technologies with unproven or uncertain performance were eliminated if they have relatively high implementation costs and/or would likely require implementation with other costly mitigation components. Technologies with uncertain or unproven performance were retained if they represented potentially cost effective mitigation and the performance can be investigated through pilot or bench scale testing.

7.1.1 Identification of Broad Categories of Potential Removal Action Alternatives

The description of the source, nature, and extent of contamination (**Sections 3.0 and 4.0**) and the RAOs developed for mining-related discharges in the Ranger District (**Section 6.0**) provide the basis for development and screening of response alternatives for the EE/CA.

The following types of response actions are generally considered removal actions under CERCLA (USDA 1996, Section I):

- Drainage controls where needed to reduce migration of hazardous substances, pollutants, or contaminants, or to prevent precipitation or runoff from other sources;
- Stabilization of berms, dikes, impoundments, and drainage or closing of lagoons where needed to maintain the integrity of the structures;
- Capping of contaminated soils or sludges where needed to reduce migration of hazardous substances into soil, groundwater or surface water, or air;
- Excavation, consolidation, or removal of highly contaminated soils from drainage or other areas where actions will reduce the spread of, or direct contact with, the contamination; and
- Containment, treatment, disposal, or incineration of hazardous materials to reduce the likelihood of human, animal, or food chain exposure.

Technologies that incorporated one or more of these actions and are applicable to coal mining related wastes were considered in developing the initial list of alternatives for evaluation for the Rock Creek abandoned mine sites. The technologies were divided into eight categories as follows:

1. Constructed wetlands – **Passive Treatment Technologies**
    a. Aerobic wetlands
    b. Anaerobic wetlands
    c. Vertical-flow wetlands
    d. Sulfate-reducing bioreactors (SRBs)

2. Limestone-based systems – **Passive Treatment Technologies**
    a. Limestone-lined channels
    b. Anoxic limestone drains (ALDs)
    c. Successive alkalinity-producing systems (SAPS)
    d. Alkaline recharge/alkaline-producing systems (APS)
    e. Limestone ponds/settling basins/leach beds
    f. Diversion wells
    g. Limestone sand treatment (dosing)

3. Source material removal to a repository or processing facility – **Reclamation Technologies**
    a. Waste pile removal
    b. Surface remining and waste pile removal
    c. AML Enhancement Rule removal

4. Hydraulic isolation using barriers and seals – **Containment Technologies**
    a. Reactor barrier walls
    b. Grouting/grout curtains
    c. Fly ash slurry injection
    d. Impermeable barriers/mine seals/plugging
    e. Blasting/collapsing mine chambers
    f. Plugging mine openings
    g. Pyrite encapsulation/inactivation

5. Submergence – **Containment Technologies**
    a. Mine chamber flooding
    b. Area inundation

6. Injection/inoculation of chemicals into mine chambers and coal waste piles – **Active Treatment Technologies**
    a. Bactericides
    b. Metal precipitating agents
    c. Flocculating/coagulating agents

7. In-line active treatment of AMD flows – **Active Treatment Technologies**
    a. Pyrolusite® treatment system
    b. Wood filters
    c. In-situ bioremediation
    d. In-line aeration and treatment

8. Conventional treatment plants – **Active Treatment Technologies**
    a. Reverse osmosis
    b. Electrodialysis
    c. Conventional treatment: neutralization/precipitation/etc.

7.1.2 Screening Criteria

The purpose of identifying and screening technology types and process options is to eliminate those technologies that are obviously unfeasible or ineffective, while retaining potentially effective options. General response actions and process options are specifically applied to either treatment of contaminated discharges or reducing or eliminating the flow of contaminants from mining-related discharges to surface water in the White Oak Creek and Rock Creek drainages. Selection of a treatment technology for application at the affected Rock Creek Sites is additionally complicated by several factors including:

- Numerous sources that have varied flow rates and contaminant concentrations;
- Inability to combine water sources for treatment due to geographical constraints;
- The remoteness and limited physical and seasonal accessibility due to steep terrain of the sites;
- The lack of a power source to identified discharges; and,
- The winter conditions at these sites.

USDA FS established five criteria to screen the initial group of candidate technologies in order to select the removal action alternatives that could most likely be applied successfully to the Site. The selected alternatives that passed this screening then received a more detailed evaluation as described in **Section 7.2** of this EE/CA. The USDA FS criteria are:

1. Will be able to raise pH, reduce acidity, and abate metals contamination (i.e., the technology must be effective).
2. Has space requirements that can be accommodated in the area available at the Site (i.e., the technology must be implementable).
3. Has proven to be effective in applications with similar AMD characteristics (i.e., the technology must be a proven technology).
4. Minimize annual and recurring maintenance and monitoring.
5. Implementation must be economically feasible, considering estimates of future budgets and other funding opportunities.

Table 22A presents an application of the five criteria to each of the listed technologies under initial consideration for the affected sites.

Four categories of treatment technologies were eliminated based on the first criterion, as they all would require expenditure of effort and funds throughout their operating life. The categories eliminated were:

- Constructed wetlands (Category 1);
- Source material removal to a repository or processing facility (Category 3);
- Hydraulic isolation using barriers and seals (Category 4);
- Submergence (Category 5);
- Injection/inoculation of chemicals into mine chambers and coal waste piles (Category 6); and,
- Treatment plants (Category 8).

Category 1, constructed wetlands, was eliminated based on the second criteria of space requirement. Most of the sites are located in steep terrain areas without the large surface areas required to process high metal loads. Further, efficient operation of anaerobic wetlands requires an incoming water pH above 6. For aerobic wetlands, they typically require pre-treatment to raise the pH above 4.

Category 3, source material removal to a repository or processing facility, including waste pile removal and remining, was eliminated due to a very high potential for the acid-forming materials to increase the generation of AMD if not properly managed. In addition, based on professional judgment, a cost benefit analysis of remining versus leaving the piles in place would show that it is better to leave the coal piles undisturbed than attempting to remine them. The current price of coal and general opinion may discourage remining. Current conditions of the refuse piles show the surface of these refuse piles have revegetated and the acid-forming materials covered and not exposed to prolonged exposure to oxygen and moisture. If the refuse piles remain buried and undisturbed, this will be a best management practice in preventing the generation of additional AMD compared to excavation for reburial and/or remining.

Category 4, hydraulic isolation using barriers and seals, was eliminated as underground conditions are unknown at all of these sites and the implementation of this category of technologies may be extremely difficult.

Category 5, submergence (mine chamber flooding or area inundation), was eliminated due to the long-term responsibility, risks, and liabilities associated with dams and reservoirs, in addition to cost estimates that were deemed infeasible for implementation.

Category 6, injection/inoculation of chemicals into mine chambers and coal waste piles, was eliminated as this treatment is often used in situations where immediate control of AMD formation is important. This option is temporary and without frequent application, the AMD formation will reoccur.

One of the technology categories, Category 7, in-line aeration and treatment, was retained as some of the sites exhibit very high acid values (> 800 mg/L $CaCO_3$), which triggered the recommendation for using an active treatment system. This option was compared to a passive system, which can be used if a shorter life expectancy of less than 25 years is acceptable. In addition, under Category 7, the only likely technology that could be implemented at the Water Tank Hollow Site is in-situ bioremediation using a permeable reactive barrier (PRB) technology.

Abandoned mines have often yielded AMD for well over a century; the length of treatment period needed is equally extensive (USEPA 2000). One other category involves passive technologies that would require regular attention, action, and even rebuilding during the lifetime of treatment. This is:

- Limestone-based systems (Category 2).

Though annual maintenance and periodic rebuilding are not preferred, these technologies, including periodic maintenance and reconstruction costs may be the most economically feasible and implementable alternatives at some locations. Innovative approaches and combinations of these technologies can reduce the maintenance requirements and provide significant improvements to water quality. Specifically, advances in the design of Category 2 treatment options will be considered due to their applicability to site conditions and economic feasibility. Additionally, this category of technologies may have applications in a secondary, "polishing" role or multiple systems can be constructed where elevated acid loads need to be addressed.

<u>Removal Action Elements Common to all Action Alternatives:</u>

Certain work elements would be employed and implemented regardless of the action alternative selected. These elements include: (1) addressing data gaps, (2) mitigating physical hazards at the Site, (3) implementing best management practices (BMPs), and (4) conducting post-removal monitoring and maintenance.

- Data Gaps – a data gap identified during the preparation of this EE/CA includes establishing seasonal flow rates for the discharges at each of the sites where a final design of a treatment system will be based on a yearly average of discharge rates.
- Administrative controls are used to restrict or control access to or use of a site. Access restrictions are potentially applicable administrative controls via mine portal closures, fencing and gates, and /or land use controls, although they do not achieve a clean-up goal; however, in addition to limiting access, these controls can provide for long-term public safety. These options are retained to complement clean up and safety actions and will be combined with other treatment options.
    - The Administrative Controls alternative would include all of the above consequences for a No Action alternative plus the following actions:
        - Signage would be placed at stream crossings and other areas where human interaction might occur. Such signage would proclaim the stream unfit for swimming and/or wading.
- Physical Hazards – May be mitigated through engineering controls such as fencing, gating and/or signs, which limit public access, or by removal of the hazard, e.g., plugging with foam or filling the hazard. For partially collapsed and/or open adits, clear soil and rock from the opening and installing a bat gate or culvert to prevent public access while maintaining potential bat habitat.
- Best Management Practices (BMPs) – During removal activities, BMPs will be employed to contain run-off, minimize erosion, and prevent contaminant transport during the removal action.
    - Specific BMPs will depend on the removal action selected and may include, but not be limited to: silt fencing, straw bales, check dams, temporary surface water diversions, sediment retention, stormwater interception, low permeability soil cover, grading and revegetation, and dust suppression.
    - Establishing a temporary staging area at each of the sites to be treated for the transfer of equipment, materials, and crew. Specific details of the staging area will depend on the Site access option and removal action options selected.
    - Soil cover over coal refuse pile – Isolation of coal refuse will prevent water and oxygen from entering the coal refuse from the top and sides, thus reducing erosion and leachate generation. Soil covers are intended to support vegetation, improve aesthetics, provide a stable surface over the coal refuse, and prevent direct human exposure to the waste piles. Soil covers can be

installed with surface grades that promote run-off and prevent ponding of water on the ground surface.

- Post-removal Monitoring and Maintenance.
  - Post-removal monitoring of the aquatic habitat at the Site would be conducted for at least 3 years following completion of the removal action to assess the overall removal action effectiveness and compliance with ARARs.
    - The post-removal monitoring will consist of biannual sampling of surface water, pore water, sediment, and benthic macroinvertebrates.
    - The sampling approach and methodology, and analytical suite will be based on a refined set of parameters to be derived from the SI.
    - If post-removal water quality monitoring indicates that water quality ARARs have not been met or that a significant risk from surface water or sediment remains, additional monitoring and evaluation may be necessary to determine the need for further removal actions.
  - Post-removal maintenance may include:
    - Maintaining the access road and gate, if present;
    - Inspecting any soil cap or refuse pile for erosion and areas of exposed waste;
    - Inspecting the reclaimed areas and surface water diversions for signs of erosion, vandalism or other damage; and
    - Making any necessary repairs, replacing any damaged soil cover due to erosion and spot seeding where necessary.

7.1.3 Results of Technology Screening

The following categories of technologies remained under consideration after the initial screening:

- Category 2 – Limestone-based systems; and,
- Category 7 – In-line active treatment of AMD flows.

USDA FS has identified a number of limestone-based treatment options and/or combination of limestone-based and in-line active treatment options from the two categories listed above that would be retained and applied for the treatment of the AMD affecting White Oak and Rock Creek (see **Table 22b**). Detailed analysis of potential removal actions at the affected Rock Creek abandoned mine sites are described in the next section.

Each of these treatment alternatives within Categories 2 and 7 are described in detail in **Section 7.2**.

7.2. Development of Alternatives

The USDA FS and its contractors will systematically integrate safety into management and work practices at all levels so that the implementation of the removal action is accomplished while protecting the public, the worker, and the environment. This will be accomplished through effective integration of safety and environmental protection management into all facets of work planning and execution. A job hazard analysis will be developed and signed by all workers and on-site personnel prior to work commencing. Appropriate personal protective equipment will be identified and employed by all workers and on-site personnel during any outside field activities at the sites, including planning, implementation, and monitoring.

7.2.1 Description of No Action Alternatives

Typically, the EE/CA process examines a set of no action alternatives as possible decision options. This allows decision-makers and the public a chance to consider the risks of leaving the site in its present condition or providing minimal protective measures by instituting administrative controls, the No Action Alternative.

7.2.2 Category 2 – Limestone-based Description of Removal Action Alternative for Acid Mine Drainage

Each of the Rock Creek abandoned mine sites has locations with unique characteristics that make some removal actions more suitable than others. The removal action alternatives for each site must incorporate one or more of the technologies previously described in **Section 7.1.1**. Based on professional engineering judgment and preliminary assessment of site-specific conditions, the removal action alternatives were selected using one of the decision flowcharts given in **Table 22c** and **Figure 27-1**. Usage of the table and flowchart results in the most reasonable removal action alternative based on a site's size, AMD chemistry, site elevation, and type of mining used. The selection of the type of passive treatment system is governed by the water chemistry and the flow, or the loading of the acidity and metals present in the water. **Figure 27-1** is a flow chart representation generally used to direct the designer to the appropriate passive treatment system. For example, if the water is net acidic, then two options exist depending upon the concentrations of dissolved oxygen, ferric iron, and/or aluminum. The first option available is the use of an anoxic limestone drain (ALD), if the dissolved oxygen, ferric iron, and/or aluminum numbers are low (typically less than 1.0 mg/L). When these parameters have been met, the use of an ALD is typically area, treatment, and cost efficient. In addition, the use of an ALD as a pre-treatment alkalinity generator has been well documented and is effective in this role. The sequence for an ALD system is: ALD-settling basin/aerobic wetland. Second option available is the use of a combination of settling pond-Successive Alkalinity producing systems (SAPS or modified vertical flow ponds [MVFPs]) and an OLC in order to meet discharge requirements.

Five process options that are generally classified as passive treatment technologies are included under this treatment category as possible alternatives for affected Rock Creek sites. These systems require minimal operations and maintenance (O&M) and are designed to capture precipitating metals in addition to raising pH. Category 2 treatment technologies evaluated in this EE/CA include:

- Vertical flow ponds
- Anoxic limestone drains
- Oxic limestone channels
- Limestone beds
- Limestone sand dumping

A few of the passive treatment systems can be reliably implemented as a single permanent solution for most AMD problems to meet ARARs limits; however, relative to active treatment, passive systems require longer retention times and greater space; provide less certain treatment efficiency; and are subject to failure in the long-term if not adequately maintained. Due to the extremely poor water quality at a few of the Rock Creek abandoned mine sites, these technologies may be installed in series to achieve the removal action objectives and/or serve as a polishing or finishing action to remove additional metals or to increase the alkalinity of the water leaving the site. The installation of a series or combination of treatment systems would allow continued operation during breakdown or maintenance, and adjustments or further testing in the case of some of the technologies that are not fully developed.

Vertical flow ponds

Vertical flow systems combine the treatment mechanisms of anaerobic wetlands and ALDs in an attempt to compensate for the limitations of both (Hendricks 1991; Duddleston et al. 1992; Kepler and McCleary 1994). Vertical-flow systems have also been called SAPS (for "successive alkalinity producing systems," Kepler and McCleary 1994) and RAPS (for "reducing and alkalinity producing systems," Watzlaf et al. 2000).

The basic elements of these systems are similar to the anaerobic wetland, but a drainage system is added to force the AMD into direct contact with the alkalinity producing substrate. The three major system elements are the drainage system, a limestone layer, and an organic layer. The system is constructed within a water-tight basin, and the drainage system is constructed with a standpipe to control water depths and ensure that the organic and limestone layers remain submerged. As the AMD waters flow downward through the organic layer, essential functions are performed: dissolved oxygen is removed by aerobic bacteria utilizing biodegradable organic compounds as energy sources, and sulfate-reducing bacteria generate alkalinity, sequester metals as sulfides, and reduce ferric iron (Fe^{3+}) to ferrous iron (Fe^{2+}). This eliminates the precipitation of ferric hydroxide and subsequent clogging and armoring of the limestone. An organic layer capable of lowering DO concentrations to < 1 mg/L is essential to prevent limestone armoring and for sulfate reduction. In the limestone layer, $CaCO_3$ is dissolved by the acidic, anoxic waters moving down to the drainage system, producing additional alkalinity. The final effluent is discharged into a settling pond for acid neutralization and metal precipitation prior to ultimate discharge.

One of the major issues identified is the plugging of vertical flow systems with aluminum precipitates. A modified vertical flow system design has been recently developed that maintains its treatment effectiveness by the flushing of aluminum precipitates out of the bed using the head provided by pooled water in the system. Passive, periodic flushing mechanisms called automatic dosing siphons have been incorporated into the vertical flow systems to increase frequency of flushing events (see **Figure 27-2**).

In a typical modified vertical flow system, acid water is ponded from 1 to 3 meters over 0.1 to 0.3 meters of organic compost, which is underlain by 0.5 to 1 meter of limestone. A series of drainage pipes below the limestone conveys the water via automatic siphon flushing into an aerobic pond where ferrous iron oxidizes and is precipitated. For influents containing significant quantities of Fe^{3+} and/or sediment, vertical-flow systems should be preceded by either a settling pond or an aerobic wetland so as to limit accumulation of solids on the organic layer surface. For treating highly acidic discharges, several vertical flow ponds can be placed in sequence, separated by settling ponds (see **Figure 27-3**). Due to the relatively steep stream gradients and discharge chemistry (net acidic water conditions) within the Rock Creek sites, an MVFP is suitable for implementation.

Anoxic limestone drains

One treatment strategy for AMD having high acidity and virtually all the iron in the ferrous state is to eliminate oxygen exposure while it is passed through a channel of limestone. An ALD is a buried channel containing limestone that is designed to limit oxygen contact with the mine discharge while alkalinity is being added (see **Figure 27-4**). ALDs over the long term have consistently provided a high level of reliability, high acid load removal, and low treatment cost. An ALD requires relatively low metal concentrations (dissolved aluminum <1 mg/L and < 1 mg/L ferric iron) and low dissolved oxygen ([DO] <1 mg/L). Aluminum (Al), however, will precipitate in the ALD and, if the concentration is too high, will tend to reduce the permeability of the drain with time, potentially leading to eventual failure. Skousen et al. (2000) recommend a maximum Al concentration of 25 mg/L when extra permeability is built into the design, but Watzlaf et al. (2000b) found ALDs could fail with Al concentrations above 21 mg/L, and Watzlaf et al. (2003) recommend Al concentrations below 1 mg/L as an extra precaution against failure.

ALDs are far less costly to construct than anaerobic or vertical flow systems and can render less costly treatment on a life-cycle basis, even if periodic but infrequent repair and replacement is required. Typically, an ALD is used upstream of aeration and a wetland system of settling ponds to allow for ferrous ion oxidation and precipitation. High aluminum and high DO limit the applicability of this alternative at sites exhibiting these water quality characteristics; however, there are a few sites with low aluminum and low dissolved oxygen concentrations within the Rock Creek abandoned mine sites.

Open limestone channels

An OLC is an adequately-sized open channel that contains large limestone and carries and treats AMD (see **Figure 27-5**). Preferably, the OLC must be on a fairly steep slope (greater than 10 percent) to ensure sufficient oxygen necessary to precipitate metals and to transport the metal precipitates down the channel, otherwise the metals (ferric iron and aluminum hydroxides) will precipitate and clog the limestone matrix, decreasing the efficiency of the system. An OLC is suited for AMD with high DO, elevated metal concentrations, and low pH. On milder slopes, there is a strong likelihood that metal sludge precipitation may cover the limestone. A settling basin may be necessary at the end depending on the metal concentrations and dissolved oxygen in the AMD. An OLC is suited for AMD with high O_2 and metal concentrations.

Limestone leach beds

A limestone leach bed (LLB) is a buried cell or trench of limestone, flow through which increases the alkalinity of non-polluted water. The limestone dissolves in the water and increases alkalinity (see **Figure 27-6**). The purpose of LLBs is to provide alkalinity to fresh water sources upstream of any AMD location or provide additional alkalinity to treated effluent from another treatment system. A mechanical drainage system is installed in the bottom of the bed, which may require periodic flushing. For leach beds to be effective, horizontal components of groundwater must be negligible. LLBs require a reliable supply of non-AMD water and with the large quantities of non-polluted surface water runoff observed at the sites during rain/snow events, there are many run-off prone areas within the Rock Creek watershed that can be redirected to boost the alkalinity of the treatment system.

Limestone sand dumping

When pH is low and the metal concentrations are relatively low, fine grained limestone may be dumped into the drainage or stream directly with the goal of dissolving the limestone before it becomes armored. Unlike dosing where the limestone is released incrementally, an entire truckload of limestone is literally dumped into the stream. Additional limestone is dumped after the previous dump has dissolved. Limestone sand dumping requires a strong stream flow and a relatively steep gradient to move the sand grains downstream and mobilize metal precipitates.

7.2.3 Category 7 – In-line Active Treatment Description of Removal Action Alternative for Acid Mine Drainage

Active treatment is generally limited to at-source treatment systems and is largely based on industrial wastewater treatment technologies. Active treatment requires a supporting infrastructure, some form of power, and periodic routine maintenance. While active technologies can potentially be very effective at removing metals to the low aquatic standards, the remoteness of some of the sites and almost inaccessibility to the sites during winter suggests that the successful implementation of these technologies could be difficult and expensive. Thus, implementation of active treatment technologies with the greatest likelihood of meeting all water quality standards would require major road improvements, a reliable source of power provided by construction of new electrical power lines and/or on-site diesel generators, construction of numerous structures to house equipment, and increased vehicular traffic necessary to move personnel and supplies. These types of infrastructure improvements would have long-term effects on the local environment and would likely impact the pristine nature of the surrounding area.

Chemical addition and precipitation

AMD treatment using this technology involves addition of chemical agents to the affected stream to change the chemistry (e.g., increase and/or decrease pH) and facilitate precipitation of insoluble mineral phases. Treatment of acidic water that contains elevated concentrations of metals through pH adjustment is a demonstrated technology capable of treating large volumes and can, under some conditions, remove metals to acceptable levels (Skousen, et al., 1998; Smith 2000). The most common order of treatment for AMD, starting with the first step, is dosing with alkali (DA) followed by oxidation (O) and sedimentation (S). Oxidation rates for dissolved metals in reduced form such as Fe^{2+} are strongly influenced by pH, and therefore, it is beneficial to raise the pH prior to the oxidation step in treatment of AMD. Sometimes a pre-treatment step precedes DAOS such as sedimentation to reduce the concentration of total suspended solids (TSS) which can affect treatment system performance.

Low pH water can be neutralized or made alkaline by the addition of readily available additives such as caustic soda or sodium hydroxide (NaOH), calcium hydroxide (hydrated lime, $Ca(OH)_2$), soda ash or sodium carbonate (Na_2CO_3) or calcium oxide (quicklime, CaO). . Of all the neutralizing chemicals, Quicklime is not only the least costly chemical for active treatment of AMD, it is also the only dry chemical that has been successfully used with a doser which does not require electrical power or daily monitoring. This machine can be powered by diverting part of the AMD stream to flow over a water wheel which mechanically turns an auger to feed quicklime from the hopper underneath an upright silo. The doser can provide the addition of lime at a rate proportional to the AMD flow rate. The mechanism for removal of constituents is primarily through precipitation, co-precipitation, and/or sorption reactions. As acidic waters increase in pH, many metals become supersaturated with respect to various mineral phases and these species are precipitated from solution. Other COCs can co-precipitate and/or sorb to surfaces of the precipitating minerals (Stumm and Morgan 1981). In addition, kinetic limitations on redox reactions and the formation of certain mineral phases are overcome at more alkaline pH levels (Cornell and Schwertmann 1996). Following metal precipitation, which removes the bulk of the metals, residual fine suspended particles are removed by micro-filtration, which is used as a polishing step. Depending on the water quality of the AMD, residual waste solids may be considered a hazardous waste.

Packaged, skid-mounted systems consisting of membrane modules, recirculation pumps, in-place cleaning loop, backpulse mechanism, instrumentation, and controls are commercially available and require a minimal footprint. The systems would require routine monitoring and maintenance and year-round access. This technology would be most applicable for treating AMD containing elevated iron and aluminum, as well as elevated acid loads. In addition, chemical treatment of mine drainage can be used solely or in conjunction with best management practices, if other options are inadequate in eliminating the production of mine drainage.

Permeable Reactive Barrier

PRBs are one of the active treatment technologies widely accepted for sustainable in situ remediation of contaminated groundwater and may be used in the management of localized seepage plumes from mine residues that contaminate shallow groundwater and/or surface waters. Those that have been installed to bio-remediate AMD operate on the same basic principles as compost bioreactors. These barriers provide chemical interactions with AMD as the polluted water flows through it. PRBs usually consist of physical porous media that interact with specific chemicals of concern in the AMD (see **Figure 27-7**). The PRB is placed in the path of polluted water flow, allowing the water to flow through it easily while the treatment process takes places through chemical or biochemical processes.

For PRBs designed to treat AMD with sulfate contamination, the barrier is generally composed of solid organic matter, like municipal compost, leaf compost, horse manure and straw, wood chips/sawdust, or chitorem® (a 100% natural product that is comprised of chitin [a natural polysaccharide], proteinaceous material, and $CaCO_3$). Construction of PRBs involves the digging of a trench or pit in the flow path of contaminated groundwater, filling the void with reactive materials (a mixture of organic solids and possibly limestone gravel) that are sufficiently permeable to allow unhindered flow of the groundwater and/or AMD seep from the waste pile.

The limestone and carbon substrate in the trench promote microbially mediated sulfate reduction, the generation of hydrogen sulfide, and the subsequent precipitation of sparingly soluble iron and other metals as sulfide minerals. Sulfate-reducing bacteria (SRB) convert SO_4^{2-} to sulfide by catalyzing the oxidation of organic carbon with the reduction of SO_4^{2-}. Chitorem®, as an example, has been used successfully as a carbon substrate in biochemical reactors, shown to remove metals including Fe, Zn, Cu, and Mn to below treatment objective levels; increasing pH from 4.55 to 6.98; and increasing alkalinity from 0 to 2,000 mg/L (as $CaCO_3$) [JRW Bioremediation, LLC].

The reaction between the sulfate and the organic substrate consumes sulfate, results in the production of H_2S and increases bicarbonate alkalinity and the pH. The sulfide produced reacts with dissolved metals and enhances the precipitation of metals as metal sulfides.

7.3. Identification of Removal Action Alternatives

Removal action alternatives identified for the Rock Creek abandoned mine sites include:

7.3.1 No Action Alternative (applicable to all the sites)

No action means that there is no active response action implemented at a site. No action can include monitoring water quality and assessing site conditions on a regular annual basis. No action is generally used as a baseline against which other response options are compared; therefore, the no action alternative is retained for consideration in the detailed analysis of alternatives.

The No Action alternative would imply the following:

- The site would remain unchanged from its present condition.
- Natural degradation would occur over time, and the pyrite found in the mine spoils would slowly oxidize and release acid mine water as precipitation and atmospheric oxygen continue to react with the pyrite.
- Seeps would occur at the current rate and would continue to impact White Oak Creek and Rock Creek, impairing their ability to establish and sustain a macroinvertebrate or fish population.
- Surface water and groundwater in the watersheds would be impaired for recreational usage and remain unusable as a drinking water source.
- No maintenance or other operational costs would be associated with this alternative.

7.3.2 Cabin Branch

- Alternative 2: 1st settling pond; MVFP; 2nd settling pond; and Pebble Quicklime dosing.
- Alternative 3: 1st settling pond; MVFP; and 2nd settling pond.

7.3.3 Big Momma

- Alternative 2: ALD; MVFP; and settling pond.
- Alternative 3: 1st settling pond; MVFP; and 2nd settling pond.
- Alternative 4: MVFP; settling pond; LSD; and Caustic Soda dosing.

7.3.4 Cooperative South

- Alternative 2: Oxic/OLC; Settling pond; and LSD.
- Alternative 3: 1st LSD; Settling pond; and LSD.

7.3.5 Jones Branch:

- Alternative 2: 1st settling pond; MVFP; 2nd settling pond; and LSD.
- Alternative 3: ALD; MVFP; settling pond; LSD; and Pebble Quicklime dosing.

7.3.6 Paint Cliff/Mine 16 Complex:

- Alternative 2: Settling pond; Pebble Quicklime dosing; and OLC.
- Alternative 3: 1st settling pond; 1st MVFP; 2nd MVFP; 2nd settling pond; and OLC.

7.3.7 Roberts Hollow:

- Alternative 2: 1st settling pond; 1st MVFP; 2nd MVFP; 2nd settling pond; and LSD.
- Alternative 3: 1st settling pond; Pebble Quicklime dosing; 2nd settling pond; and LSD.

7.3.8 Poplar Spring:

- Alternative 2: 1st settling pond; MVFP; LB; and 2nd settling pond.
- Alternative 3: 1st settling pond; MVFP; 2nd settling pond; LB; and OLC.

7.3.9 Koger Fork:

- Alternative 2: Soil Cover BMP; Pebble Quicklime dosing; and OLC.
- Alternative 3: Soil Cover BMP; OLC; and LSD.

7.3.10 Water Tank:

- Alternative 2: Soil Cover BMP; and PRB wall.
- Alternative 3: Soil Cover BMP; and LSD.

7.3.11 Grassy Fork:

- Alternative 2: LSD.
- Alternative 3: Pebble Quicklime dosing; and LSD.

7.4. Analysis of Selected Removal Action Alternatives

Once a set of potential removal action alternatives is selected for each site, the attempt is made to quantitatively evaluate the alternatives to a set of criteria. The defined alternatives described in **Section 7.1.1** are evaluated against the short- and long-term aspects of three broad criteria: effectiveness, implementability, and cost. These criteria are fully described below.

7.4.1 Effectiveness

To achieve consistency with the removal action objectives identified in **Section 6.0**, the effectiveness criterion will assess the success in achieving the principal objectives of both long-term and short-term protection of public health and the environment.

Environmental protection will consider the degree to which resultant low pH and elevated toxic metals in AMD from the Rock Creek abandoned mine sites will be brought to acceptable ranges, thereby reducing the potential for exposure to environmental receptors, such as fish, macroinvertebrate species, and wildlife. Additionally, the evaluation will consider factors normally assessed under NEPA, including immediate environmental impacts that may result from implementing the removal action.

The alternative will be evaluated as to its effectiveness in reducing the toxicity, mobility, and/or volume of the contaminants of concern. Rock Creek reportedly has some of the poorest water quality in the nation among coal-mined areas; removal actions taken will need to be robust enough to mitigate this poor quality. This component also involves an assessment of the potential for future exposure from residual conditions at the site, as well as the potential for long-term failure of the alternative and any potential threats from such a failure.

The evaluation of this criterion will focus on the extent to which the completed action reduces or mitigates identified threats, as well as compliance with chemical-specific ARARs and TBCs. This evaluation will also consider the extent to which the actions meet the location-specific ARARs and TBCs, particularly those pertaining to environmentally-sensitive areas. In addition to these, consideration will also be given to short-term protection of workers during the initial construction and implementation.

7.4.2 Implementability

The implementability of an alternative is defined by its technical and administrative feasibilities.

7.4.2.1 Technical Feasibility

The factors evaluated regarding an alternative's technical feasibility include:

- The ability to construct and operate the alternative, considering unknowns that may lead to schedule delays;
- Infrastructure requirements (power supply);
- The ability to meet the required process efficiencies or performance goals;
- Remoteness of location, accessibility, and climatic conditions;
- Compliance with action-specific ARARs and TBCs; and
- The previously demonstrated performance of a technology.

The technical feasibility evaluation also considers the availability of necessary equipment, materials, personnel, expertise, etc., including any measures that may be required at the completion of the action, such as monitoring, and availability of a responsible party to assume these activities.

7.4.2.2. Administrative Feasibility

The evaluation of administrative feasibility of an alternative includes the likelihood of public acceptance, activities necessary for coordination with other agencies, and the ability to obtain necessary approvals or permits. Consideration will be given to the necessary acquisition of easements and right-of-ways where applicable, and to the potential impact on adjacent properties.

7.4.3 Cost

Evaluate each alternative to determine the projected costs. Consider the following costs:

- Capital costs;
- O&M costs (annual); and,
- Periodic costs (replacement or abandonment).

The total cost of an alternative is the final criterion to be considered. This criterion includes direct capital costs, engineering and management costs (indirect capital costs), operation and maintenance costs, post-removal site control costs (if applicable), an allowance for contingencies, and present worth values in order to facilitate comparisons.

The cost estimates are based only on conceptual designs and are intended only for alternative comparison purposes. They are best utilized for their relative value rather than for actual value. The best estimates here will only provide a “ballpark” number with, at best, an accuracy of ±25 percent. According to Forest Service Region 10, “it is tough to get defensible cost estimates at this stage of the project” (Maas, undated). Actual costs will be more closely estimated during the bid and procurement process.

Cost estimates are given in **Appendix E** for those site areas/alternative combinations that seem reasonable to consider based on knowledge of the sites and professional engineering judgment.

7.4.3.1 Direct Capital Costs

Direct capital costs include costs associated with implementation of the applied technology, including mobilization and demobilization of heavy equipment, construction labor costs, equipment and materials necessary for building, earth moving, road construction, and drilling.

Direct capital costs were obtained for each of the alternatives by first developing line-item unit costs from published case studies, actual costs from representative projects, vendor information, etc. Total direct costs were then calculated using this unit cost and information known or estimated about each site area.

Unit costs for each alternative were derived from the following sources:

- EPA’s Best Management Practices guidance manual for remining (USEPA 2000). This manual collected actual data from over 100 remining case studies employing various BMPs. It then employed the tools of statistical analysis to determine best-fit linear regression models to predict costs on a unit basis. These models were used in **Appendix E** spreadsheets to produce cost numbers for various alternatives. Since most of the case studies were conducted in earlier years, the manual projected the costs onto current dollars (the year 2000 at the time of its writing) by using a ratio of Cost Construction Index (CCI) values obtained from the U.S. Census Bureau website. This project extrapolates the dollar values still further into 2015 dollars using the same ratio technique.
- The Office of Surface Mining and Reclamation (OSMRE) treatment cost manual (US OSMRE 2000). This manual, prepared by Tetra Tech, Inc., includes unit costs for line item activities involved in a range of AMD treatment options. As above, these dollars were projected forward onto current dollars using a ratio of CCI values.
- Information obtained from current and past USDA FS projects and projects conducted or overseen by the Office of Surface Mining, state agencies of West Virginia, Ohio, and Pennsylvania, and universities, such as West Virginia University. Some alternatives, or activities within the alternatives, have already been implemented on USDA FS property in the Daniel Boone National Forest or other National Forests. Where actual costs were available, these dollar numbers were considered to be fairly accurate and applicable and were used as much as possible as part of the estimates.
- “AMDTREAT” (version 5.0.2) cost estimation software from the OSMRE.

- Proposed and actual costs submitted for typical PRB projects.
- State of Kentucky and vendor information.
- Professional engineering judgment.

7.4.3.2. Indirect Capital Costs

Indirect capital costs include those that are incurred for engineering and design, legal and licensing fees (if any), and other fees not directly related to actual installation, such as public and community relations. For purposes of this cost estimate, indirect costs are estimated at 16% of the direct capital costs (OSMRE 1999) for each alternative.

7.4.3.3. Operations and Maintenance Costs

O&M costs may be a significant part of a project budget. Though removal action alternatives considered in this project include only those that entail minimal post-implementation O&M costs, most removal alternatives will require some form of maintenance, whether planned or unplanned. O&M costs will vary between the alternatives and are considered and estimated where applicable. Obtaining USDA FS funding for long-term O&M is problematic, and the difficulty of identifying O&M funding has to be considered when evaluating alternatives. The USDA FS is looking for opportunities to identify and obtain funding for long-term O&M.

7.4.3.4. Annual Post-Removal Site Control (APRSC) Costs

The APRSC costs that are anticipated include monitoring/analytical costs and reporting costs. These costs are included in estimates here but are considered to be part of the annual operating budget for the USDA FS. Similar to long-term O&M, identifying USDA FS funding for APRSC costs has proven problematic, and the USDA FS is currently engaged in nationwide discussions on opportunities to identify APRSC funding.

7.4.3.5. Contingency Allowance

Due to the inherent high level of uncertainty at this conceptual stage of the process, an allowance for contingencies of 20% (US OSMRE 2000) is introduced at this stage of the cost analysis and applied to the total project cost.

Several items that may have an effect on the actual implementation cost of the alternatives were not included in the cost estimates. Typically, omission of these cost items would not affect the comparative analysis of the alternatives but would affect the actual implementation cost. The assumptions used in defining the alternative for cost estimating purposes are listed below.

- Treatment systems costs are based on available flow data measured during the 2014 sampling event. Flows from most sources are known to vary seasonally, and therefore, the amount of flow data available is limited. Actual remedy implementation would require consideration of peak flows.
- Road construction/access improvements were included. Some level of access improvement would be required for the implementation and operation of selected remedies regardless of which alternative(s) is selected.

7.4.4 Analysis of Cabin Branch Removal Alternatives

The alternatives developed for Cabin Branch involves AMD source reduction by limiting surface water runoff, and water treatment using either passive or active varieties of removal technologies.

7.4.4.1 Alternative 2 – 1st Settling pond; MVFP; Pebble Quicklime; and 2nd settling Pond

Alternative 2 utilizes both active and passive treatment technologies. Water from the discharge is first directed into a settling pond, which collects the water for a set period of time. This allows the suspended solids to precipitate out of the water. Solids such as iron (yellow boy or iron oxide) will settle to the bottom of the pond and collect there. This is followed by the MVFP treatment train, which relies on water neutralization with limestone, biological sulfate reduction to precipitate metal sulfides, and an aeration/neutralization cell for the removal of residual aluminum and manganese. Active treatment occurs through the addition of quicklime (CaO) after the MVFP treatment. This addition polishes the treated water through raising the pH. This is followed by another settling pond prior to discharge into White Oak Creek.

These alternative costs include the following:

a. Clearing access road for equipment and vehicle access;
b. Clearing and grubbing;
c. Stormwater runoff diversion;
d. 200-foot ditch to route discharge into channel;
e. Lined settling pond that distributes influent AMD across the width of the treatment unit using manifolds, level spreaders, open water fore bays or baffles;
    i. Sludge removal and disposal once every 5 years
f. MVFP;
g. Pebble Quick Lime Doser; and
h. 2nd Lined settling pond.

Effectiveness:

The combined treatment technologies in this alternative would provide significant alkalinity improvement and result in approximate load reductions to White Oak Creek for net acidity and metals. The contaminant volume in surface water would be significantly reduced and the improvement in surface water quality would reduce risks to human health and the environment from exposure to surface water at the site. This alternative would achieve the RAOs and comply with ARARs to the extent practical. Short-term effectiveness should be high based on an immediate improvement to surface water; however, the long-term effectiveness will depend on the longevity of neutralizing capacity in the treatment components. Periodic O&M will be required to monitor surface water quality and to replenish or replace neutralizing materials as they become depleted or armored with metal hydroxides. Diversion and bypass of storm water should improve long-term effectiveness by minimizing water chemistry fluctuations in the AMD and minimizing potential damage from high flows during large storm events. The operational life of an MVFP can be reduced by the accumulation of precipitated metals. Effective flushing of precipitated solids is essential to prevent clogging and to ensure long-term operation.

Implementability:

This alternative is both technically and administratively feasible. The proposed technologies are implementable using standard construction methods and equipment, and the required resources are readily available.

Costs:

The estimated costs for Alternative 2 are based on professional judgement, experience at similar sites, and estimates using the AMDTreat (version 5.0.2) software. The total estimated capital cost for Alternative 2 is $356,124. The estimated average annual O&M cost for Alternative 2 is $18,496.

7.4.4.2. Alternative 3 – 1st Settling pond; MVFP; and 2nd settling Pond

Alternative 3 uses only passive treatment technologies. Similar to Alternative 2, water from the discharge is first directed into a settling pond. This is followed by the MVFP treatment train; however, instead of the discharge being polished through the addition of CaO after the MVFP, the water instead flows into another settling pond prior to discharge into White Oak Creek. By using two settling ponds, metals are oxidized and precipitated before and after the MVFP. These alternative costs include the following:

a. Clearing access road for equipment and vehicle access;
b. Clearing and grubbing;
c. Stormwater runoff diversion;
d. 200-foot ditch to route discharge into channel;
e. Lined settling pond that distributes influent AMD across the width of the treatment unit using manifolds, level spreaders, open water fore bays or baffles;
    i. Sludge removal and disposal once every 5 years
f. MVFP with automatic dosing siphon/flushing;
g. Lined settling pond; and
    i. Sludge removal and disposal every 5 years
h. LSD.

Effectiveness:

The passive treatment technologies in this alternative would provide significant alkalinity improvement and result in approximate load reductions to White Oak Creek for net acidity and metals. The contaminant volume in surface water would be significantly reduced and the improvement in surface water quality would reduce risks to human health and the environment from exposure to surface water at the site. This alternative would achieve the RAOs and comply with ARARs to the extent practical. Short-term effectiveness should be high based on an immediate improvement to surface water; however, the long-term effectiveness will depend on the longevity of neutralizing capacity in the passive treatment components. Periodic O&M will be required to monitor surface water quality and to replenish or replace neutralizing materials as they become depleted or armored with metal hydroxides. Diversion and bypass of storm water should improve long-term effectiveness by minimizing water chemistry fluctuations in the AMD and minimizing potential damage from high flows during large storm events. The operational life of an MVFP can be reduced by the accumulation of precipitated metals. Effective flushing of precipitated solids is essential to prevent clogging and to ensure long-term operation.

Implementability:

This alternative is both technically and administratively feasible. The proposed technologies are implementable using standard construction methods and equipment, and the required resources are readily available.

Costs:

The estimated costs for Alternative 3 are based on professional judgement, experience at similar sites, and estimates using the AMDTreat (version 5.0.2) software. The total estimated capital cost for Alternative 3 is $287,814. The estimated average annual O&M cost for Alternative 3 is $23,376.

7.4.5 Analysis of Big Momma Removal Alternatives

The alternatives developed for Big Momma involves AMD source reduction by limiting surface water runoff, and water treatment using either passive or active varieties of removal technologies.

7.4.5.1 Alternative 2 – ALD; MVFP; and Settling Pond

Alternative 2 uses only passive treatment technologies. AMD is first directed into an ALD. The water traverses the ALD, flows into the MVFP treatment train, and then discharges into a settling pond prior to discharging into White Oak Creek. These alternative costs include the following:

a. Access road for equipment and vehicle access;
b. Clearing and grubbing;
c. Stormwater runoff diversion;
d. ALD;
e. MVFP with automatic dosing siphon/flushing; and
f. Lined settling pond.
    i. Sludge removal and disposal every 5 years

Effectiveness:

The passive treatment technologies in this alternative would provide significant alkalinity improvement and result in approximate load reductions to White Oak Creek for net acidity and metals. The contaminant volume in surface water would be reduced and the improvement in surface water quality would reduce risks to human health and the environment from exposure to surface water at the site. This alternative would achieve the RAOs and comply with ARARs to the extent practical. Short-term effectiveness should be high based on an immediate improvement to surface water; however, the long-term effectiveness will depend on the longevity of neutralizing capacity in the passive treatment components. Periodic O&M will be required to monitor surface water quality and to replenish or replace neutralizing materials as they become depleted or armored with metal hydroxides. Diversion and bypass of storm water runoff should improve long-term effectiveness by minimizing water chemistry fluctuations in the AMD and minimizing potential damage from high flows during large storm events. The operational life of an MVFP can be reduced by the accumulation of precipitated metals. Effective flushing of precipitated solids is essential to prevent clogging and to ensure long-term operation.

Implementability:

This alternative is both technically and administratively feasible. The proposed technologies are implementable using standard construction methods and equipment, and the required resources are readily available.

Costs:

The estimated costs for Alternative 2 are based on professional judgement, experience at similar sites, and estimates using the AMDTreat (version 5.0.2) software. The total estimated capital cost for Alternative 2 is $404,588. The estimated average annual O&M cost for Alternative 2 is $18,496.

7.4.5.2. Alternative 3 – 1st Settling Pond; MVFP; and 2nd Settling Pond

Alternative 3 uses only passive treatment technologies. AMD is first directed into a settling pond. The water traverses the settling pond, flows into the MVFP treatment train, and then discharges into a settling pond prior to discharging into White Oak Creek. These alternative costs include the following:

a. Access road for equipment and vehicle access;
b. Clearing and grubbing;
c. Stormwater runoff diversion;
d. ALD;
e. MVFP with automatic dosing siphon/flushing; and
f. Lined settling pond.
    i. Sludge removal and disposal every 5 years

Effectiveness:

The passive treatment technologies in this alternative would provide significant alkalinity improvement and result in approximate load reductions to White Oak Creek for net acidity and metals. The contaminant volume in surface water would be significantly reduced and the improvement in surface water quality would reduce risks to human health and the environment from exposure to surface water at the site. This alternative would achieve the RAOs and comply with ARARs to the extent practical. Short-term effectiveness should be high based on an immediate improvement to surface water; however, the long-term effectiveness will depend on the longevity of neutralizing capacity in the passive treatment components. Periodic O&M will be required to monitor surface water quality and to replenish or replace neutralizing materials as they become depleted or armored with metal hydroxides. Diversion and bypass of storm water should improve long-term effectiveness by minimizing water chemistry fluctuations in the AMD and minimizing potential damage from high flows during large storm events. The operational life of an MVFP can be reduced by the accumulation of precipitated metals. Effective flushing of precipitated solids is essential to prevent clogging and to ensure long-term operation.

Implementability:

This alternative is both technically and administratively feasible. The proposed technologies are implementable using standard construction methods and equipment, and the required resources are readily available.

Costs:

The estimated costs for Alternative 3 are based on professional judgement, experience at similar sites, and estimates using the AMDTreat (version 5.0.2) software. The total estimated capital cost for Alternative 3 is $392,217. The estimated average annual O&M cost for Alternative 3 is $23,376.

7.4.5.3. Alternative 4 – Settling Pond; MVFP; Caustic Soda; and LSD

Alternative 4 utilizes the same settling pond and MVFP flow described in Alternative 3; however, instead of a second flow pond following the MVFP, the water is polished through limestone sand dumping and the addition of NaOH prior to discharging into White Oak Creek. These alternative costs include the following:

a. Access road for equipment and vehicle access;
b. Clearing and grubbing;
c. Stormwater runoff diversion;
d. Lined Settling pond – sludge removal and disposal every 5 years;
e. MVFP with automatic dosing siphon/flushing; and,
f. Caustic soda addition; and
g. Limestone sand dumping.

Effectiveness:

The combined treatment technologies in this alternative would provide significant alkalinity improvement and result in approximate load reductions to White Oak Creek for net acidity and metals. The contaminant volume in surface water would be significantly reduced and the improvement in surface water quality would reduce risks to human health and the environment from exposure to surface water at the site. This alternative would achieve the RAOs and comply with ARARs to the extent practical. Short-term effectiveness should be high based on an immediate improvement to surface water; however, the long-term effectiveness will depend on the longevity of neutralizing capacity in the treatment components. Periodic O&M will be required to monitor surface water quality and to replenish or replace neutralizing materials as they become depleted or armored with metal hydroxides. Diversion and bypass of storm water should improve long-term effectiveness by minimizing water chemistry fluctuations in the AMD and minimizing potential damage from high flows during large storm events. The operational life of an MVFP can be reduced by the accumulation of precipitated metals. Effective flushing of precipitated solids is essential to prevent clogging and to ensure long-term operation.

Implementability:

This alternative is both technically and administratively feasible. The proposed technologies are implementable using standard construction methods and equipment, and the required resources are readily available.

Costs:

The estimated costs for Alternative 4 are based on professional judgement, experience at similar sites, and estimates using the AMDTreat (version 5.0.2) software. The total estimated capital cost for Alternative 4 is $329,571. The estimated average annual O&M cost for Alternative 4 is $18,496.

7.4.6 Analysis of Cooperative South Removal Alternatives

The alternatives developed for Cooperative South involve AMD source reduction by passive treatment resulting in pH reduction, neutralization, and metal removal. Cooperative South has two branches: a left and a right. The left has a more neutral pH than the right, and has a higher level of AMD contamination. The two treatment options are designed to raise the pH of the left tributary, which is longer and easier to access, such that the confluence of the two will attain near-neutral pH. Alternative 2 utilizes an OLC in order to raise the left tributary's pH; Alternative 3 utilizes limestone sand dumping instead. After either step, the effluent from the combined discharges at Cooperative South is passed through a settling pond for removal of residual manganese, aluminum, and sulfides. After the settling pond, both alternatives utilize limestone sand dumping as a final polishing step for the effluent.

7.4.6.1 Alternative 2 – OLC; Settling Pond; and LSD

Alternative 2 uses only passive treatment technologies. AMD from the left tributary is first directed into an OLC and directed toward the confluence with the right tributary. Discharges from the two tributaries, one with low pH and another with a higher alkalinity, converge in a settling pond where the overall pH is raised. The water from the settling is further amended with LSD prior to discharging into White Oak Creek. These alternative costs include the following:

a. Access road for equipment and vehicle access;
b. Clearing and grubbing;
c. Stormwater runoff diversion;
d. OLC;
e. Lined settling pond; and
    i. Sludge removal and disposal every 5 years
f. LSD.

Effectiveness:

The passive treatment technologies in this alternative would provide significant alkalinity improvement and result in approximate load reductions to White Oak Creek for net acidity and metals. The contaminant volume in surface water would be significantly reduced and the improvement in surface water quality would reduce risks to human health and the environment from exposure to surface water at the site. This alternative would achieve the RAOs and comply with ARARs to the extent practical. Short-term effectiveness should be high based on an immediate improvement to surface water; however, the long-term effectiveness will depend on the longevity of neutralizing capacity in the passive treatment components. Periodic O&M will be required to monitor surface water quality and to replenish or replace neutralizing materials as they become depleted or armored with metal hydroxides.

Implementability:

This alternative is both technically and administratively feasible. The proposed technologies are implementable using standard construction methods and equipment, and the required resources are readily available.

Costs:

The estimated costs for Alternative 2 are based on professional judgement, experience at similar sites, and estimates using the AMDTreat (version 5.0.2) software. The total estimated capital cost for Alternative 2 is $171,414. The estimated average annual O&M cost for Alternative 2 is $18,496.

7.4.6.2. Alternative 3 – 1st LSD, Settling pond; and 2nd LSD

Alternative 3 uses only passive treatment technologies. AMD from the left tributary is first treated using sand-sized limestone (via limestone sand dumping) to increase its pH before it converges with the right tributary. Once the two tributaries combine, the resulting AMD will have an overall higher pH prior to flowing into a settling pond. The water from the settling is further amended with LSD prior to discharging into White Oak Creek. The costs for this alternative include the following:

a. Access road for equipment and vehicle access;
b. Clearing and grubbing;
c. Stormwater runoff diversion;
d. LSD
e. Lined settling pond; and
    i. Sludge removal and disposal every 5 years
f. LSD.

Effectiveness:

The passive treatment technologies in this alternative would provide substantial alkalinity improvement and result in approximate load reductions to White Oak Creek for net acidity and metals. The contaminant volume in surface water would be reduced and the improvement in surface water quality would reduce risks to human health and the environment from exposure to AMD-impacted surface water at the site. This alternative would achieve the RAOs and comply with ARARs to the extent practical. Short-term effectiveness should be high based on an immediate improvement to surface water quality; however, the long-term effectiveness will depend on the longevity of neutralizing capacity in the passive treatment components. Additionally, the effectiveness of Alternative 3 may be less than that of Alternative 2 in terms of raising the pH of the water in order to precipitate metals in the settling pond. Periodic O&M will be required to monitor surface water quality and to replenish or replace neutralizing materials as they become depleted or armored with metal hydroxides.

Implementability:

This alternative is both technically and administratively feasible. The proposed technologies are implementable using standard construction methods and equipment, and the required resources are readily available.

Costs:

The estimated costs for Alternative 3 are based on professional judgement, experience at similar sites, and estimates using the AMDTreat (version 5.0.2) software. The total estimated capital cost for Alternative 3 is \$165,244. The estimated average annual O&M cost for Alternative 3 is \$18,496.

7.4.7 Analysis of Jones Branch Removal Alternatives

The alternatives developed for Jones Branch involves AMD source reduction by limiting surface water runoff, and water treatment using either passive or active varieties of removal technologies.

7.4.7.1 Alternative 2 – 1st Settling pond; MVFP; 2nd settling pond; and LSD

Alternative 2 uses only passive treatment technologies. Water from the discharge is directed into a settling pond. After a set period of time, the water flows into the MVFP treatment train, and then another settling pond. Lastly, the water is polished with limestone sand dumping in order to raise the pH. These alternative costs include the following:

a. Access road for equipment and vehicle access;
b. Clearing and grubbing;
c. Stormwater runoff diversion;
d. Lined Settling Pond with sludge removal and disposal every 5 years;
e. MVFP with automatic dosing siphon/flushing;
f. Lined Settling pond with sludge removal and disposal every 5 years; and
g. LSD.

Effectiveness:

The passive treatment technologies in this alternative would provide significant alkalinity improvement and result in approximate load reductions to White Oak Creek for net acidity and metals. The contaminant volume in surface water would be reduced and the improvement in surface water quality would reduce risks to human health and the environment from exposure to surface water at the site. This alternative would achieve the RAOs and comply with ARARs to the extent practical. Short-term effectiveness should be high based on an immediate improvement to surface water; however, the long-term effectiveness will depend on the longevity of neutralizing capacity in the passive treatment components. Periodic O&M will be required to monitor surface water quality and to replenish or replace neutralizing materials as they become depleted or armored with metal hydroxides. Diversion and bypass of storm water runoff should improve long-term effectiveness by minimizing water chemistry fluctuations in the AMD and minimizing potential damage from high flows during large storm events. The operational life of an MVFP can be reduced by the accumulation of precipitated metals. Effective flushing of precipitated solids is essential to prevent clogging and to ensure long-term operation.

Implementability:

This alternative is both technically and administratively feasible. The proposed technologies are implementable using standard construction methods and equipment, and the required resources are readily available.

Costs:

The estimated costs for Alternative 2 are based on professional judgement, experience at similar sites, and estimates using the AMDTreat (version 5.0.2) software. The total estimated capital cost for Alternative 2 is $441,220. The estimated average annual O&M cost for Alternative 2 is $23,376.

7.4.7.2. Alternative 3 – ALD; MVFP; settling pond; Pebble Quicklime; and LSD

Alternative 3 uses only passive treatment technologies. AMD is first directed into an ALD. The water traverses the ALD, flows into the MVFP treatment train, and then discharges into a settling pond prior to discharging into White Oak Creek. An option for the old adit with the concrete flooring would be to install a 10 to 20 ft. long ALD traversing the length of the seeps and periodically monitoring to evaluate the need to replenish the limestone. These alternative costs include the following:

a. Access road for equipment and vehicle access;
b. Clearing and grubbing;
c. Stormwater runoff diversion;
d. ALD – for the main discharge and the old adit discharge;
e. MVFP with automatic dosing siphon/flushing;
f. Lined Settling Pond with sludge removal and disposal every 5 years;
g. Pebble Quicklime addition; and
h. Limestone sand dumping.

Effectiveness:

The combined treatment technologies in this alternative would provide significant alkalinity improvement and result in approximate load reductions to White Oak Creek for net acidity and metals. The contaminant volume in surface water would be significantly reduced and the improvement in surface water quality would reduce risks to human health and the environment from exposure to surface water at the site. This alternative would achieve the RAOs and comply with ARARs to the extent practical. Short-term effectiveness should be high based on an immediate improvement to surface water; however, the long-term effectiveness will depend on the longevity of neutralizing capacity in the treatment components. Periodic O&M will be required to monitor surface water quality and to replenish or replace neutralizing materials as they become depleted or armored with metal hydroxides. Diversion and bypass of storm water should improve long-term effectiveness by minimizing water chemistry fluctuations in the AMD and minimizing potential damage from high flows during large storm events. The operational life of an MVFP can be reduced by the accumulation of precipitated metals. Effective flushing of precipitated solids is essential to prevent clogging and to ensure long-term operation.

Implementability:

This alternative is both technically and administratively feasible. The proposed technologies are implementable using standard construction methods and equipment, and the required resources are readily available.

Costs:

The estimated costs for Alternative 3 are based on professional judgement, experience at similar sites, and estimates using the AMDTreat (version 5.0.2) software. The total estimated capital cost for Alternative 3 is $375,461. The estimated average annual O&M cost for Alternative 3 is $18,496.

7.4.8 Analysis of Paint Cliff/Mine 16 Complex Removal Alternatives

The alternatives developed for Paint Cliff involves AMD source reduction by limiting surface water runoff, and water treatment using either passive or active varieties of removal technologies.

7.4.8.1 Alternative 2 – 1st Settling pond; Pebble Quicklime; and OLC

Alternative 1 utilizes both active and passive treatment technologies. The site has an existing MVFP, with OLCs directing flow to and from the MVFP. This alternative, however, adds to the existing system by adding another settling pond and the active treatment of adding CaO to raise pH. Conventional chemical treatment system will use mechanical feeders, mixers and a settling pond in various combinations to provide AMD treatment.

A second or separate line of AMD discharge from the existing line will be first directed into a settling pond, which will collect the water for a set period of time. This allows the suspended solids to precipitate out of the water. Solids such as iron (yellow boy or iron hydroxide) will settle to the bottom of the pond and collect there. This will be followed by the addition of CaO, the main treatment step. Discharge from this step will be directed through an OLC for additional polishing prior to discharging into the two existing settling ponds on site. The upgrade will be designed to supplement the effectiveness of the existing system.

These alternative costs include the following:

a. Clearing access road for equipment and vehicle access;
b. Clearing and grubbing;
c. Stormwater runoff diversion;
d. Lined settling pond that distributes influent AMD across the width of the treatment unit using manifolds, level spreaders, open water fore bays or baffles;
    i. Sludge removal and disposal once every 5 years
e. Pebble Quick Lime Doser; and
f. OLC.

Effectiveness:

The mainly active treatment technology in this alternative that supplements the existing system would provide significant alkalinity improvement and result in approximate load reductions to Rock Creek for net acidity and metals. The contaminant volume in surface water would be significantly reduced and the improvement in surface water quality would reduce risks to human health and the environment from exposure to surface water at the site. This alternative would achieve the RAOs and comply with ARARs to the extent practical. Short-term effectiveness should be high based on an immediate improvement to surface water; however, the long-term effectiveness will depend on the longevity of neutralizing capacity in the treatment components. Periodic O&M will be required to monitor surface water quality and to replenish or replace neutralizing materials as they become depleted or armored with metal hydroxides. Diversion and bypass of storm water should improve long-term effectiveness by minimizing water chemistry fluctuations in the AMD and minimizing potential damage from high flows during large storm events.

Implementability:

This alternative is both technically and administratively feasible. The proposed technologies are implementable using standard construction methods and equipment, and the required resources are readily available.

Costs:

The estimated costs for Alternative 2 are based on professional judgement, experience at similar sites, and estimates using the AMDTreat (version 5.0.2) software. The total estimated capital cost for Alternative 2 is $433,632. The estimated average annual O&M cost for Alternative 2 is $18,496.

7.4.8.2. Alternative 3 – 1st Settling pond; 1st MVFP; 2nd MVFP; 2nd settling Pond; and OLC

Alternative 3 uses only passive treatment technologies and would require constructing a completely new treatment system at the site. Similar to Alternative 2, water from the discharge is first directed into a settling pond. This is followed by two MVFPs constructed in succession. The treated discharge from the second MVFP flows into another settling pond prior to discharge into Rock Creek. By using two MVFPs and settling ponds, the discharges are adequately neutralized, biologically reduced by sulfate reducing bacteria, and metals oxidized and precipitated. Another step of polishing with OLC is added to further boost the pH levels and possible metals precipitation prior to discharging into Rock Creek. These alternative costs include the following:

a. Clearing access road for equipment and vehicle access;
b. Clearing and grubbing;
c. Stormwater runoff diversion;
d. Lined settling pond that distributes influent AMD across the width of the treatment unit using manifolds, level spreaders, open water fore bays or baffles;
e. Two (2) MVFPs constructed in succession and equipped with automatic dosing siphon/flushing;
f. Lined Settling pond with sludge removal and disposal every 5 years; and,
g. Open Limestone Channel.

Effectiveness:

The passive treatment technologies in this alternative would provide significant alkalinity improvement and result in approximate load reductions to Rock Creek for net acidity and metals. The contaminant volume in surface water would be significantly reduced and the improvement in surface water quality would reduce risks to human health and the environment from exposure to surface water at the site. This alternative would achieve the RAOs and comply with ARARs to the extent practical. Short-term effectiveness should be high based on an immediate improvement to surface water; however, the long-term effectiveness will depend on the longevity of neutralizing capacity in the passive treatment components. Periodic O&M will be required to monitor surface water quality and to replenish or replace neutralizing materials as they become depleted or armored with metal hydroxides. Diversion and bypass of storm water should improve long-term effectiveness by minimizing water chemistry fluctuations in the AMD and minimizing potential damage from high flows during large storm events. The operational life of the MVFPs can be reduced by the accumulation of precipitated metals. Effective flushing of precipitated solids is essential to prevent clogging and to ensure long-term operation.

Implementability:

This alternative is both technically and administratively feasible. The proposed technologies are implementable using standard construction methods and equipment, and the required resources are readily available.

Costs:

The estimated costs for Alternative 3 are based on professional judgement, experience at similar sites, and estimates using the AMDTreat (version 5.0.2) software. The total estimated capital cost for Alternative 3 is $555,182. The estimated average annual O&M cost for Alternative 3 is $18,496.

7.4.9 Analysis of Roberts Hollow Removal Alternatives

The alternatives developed for Roberts Hollow involves AMD source reduction by limiting surface water runoff, and water treatment using either passive or active varieties of removal technologies.

7.4.9.1 Alternative 2 – 1st Settling pond; 1st MVFP; 2nd MVFP; 2nd settling Pond; and LSD

Alternative 2 utilizes passive treatment technologies. Water from the discharge is first directed into a settling pond, which collects the water for a set period of time. This allows the suspended solids to precipitate out of the water. Solids such as iron (yellow boy or iron oxide) will settle to the bottom of the pond and collect there. This is followed by two MVFPs constructed in succession. The treated discharge from the second MVFP flows into another settling pond prior to discharge into Rock Creek. The MVFP treatment trains rely on water neutralization with limestone, biological sulfate reduction to precipitate metal sulfides, and an aeration/neutralization cell for the removal of residual aluminum and manganese. This is followed by another settling pond prior to discharge into Rock Creek.

These alternative costs include the following:

1. Limestone sand dumping at sample location #16/#18;
2. Between sample locations #16/#18 and #19/#54;
    a. First MVFP equipped with automatic dosing siphon/flushing system;
    b. Lined settling pond;
3. Second MVFP after locations #19/#54 equipped with automatic siphon/flushing system;
4. Lined settling pond;
    a. Along the toe of coal refuse; and
5. Limestone sand dumping station past sample locations #19/#54 and before the highway and Rock Creek.

Effectiveness:

The use of two MVFP systems in a series in this alternative would provide significant alkalinity improvement and result in approximate load reductions to Rock Creek for net acidity and metals. The contaminant volume in surface water would be significantly reduced and the improvement in surface water quality would reduce risks to human health and the environment from exposure to surface water at the site. This alternative would achieve the RAOs and comply with ARARs to the extent practical. Short-term effectiveness should be high based on an immediate improvement to surface water; however, the long-term effectiveness will depend on the longevity of neutralizing capacity in the treatment components. Periodic O&M will be required to monitor surface water quality and to replenish or replace neutralizing materials as they become depleted or armored with metal hydroxides. The operational life of the MVFPs can be reduced by the accumulation of precipitated metals. Effective flushing of precipitated solids is essential to prevent clogging and to ensure long-term operation.

Implementability:

This alternative is both technically and administratively feasible. The proposed technologies are implementable using standard construction methods and equipment, and the required resources are readily available.

Costs:

The estimated costs for Alternative 2 are based on professional judgement, experience at similar sites, and estimates using the AMDTreat (version 5.0.2) software. The total estimated capital cost for Alternative 2 is $463,998. The estimated average annual O&M cost for Alternative 2 is $23,376.

7.4.9.2. Alternative 3 – Settling pond; Pebble Quicklime; and LSD

Alternative 3 uses mainly an active treatment technology with a limestone-based treatment step for polishing. AMD is first directed into a settling pond that collects the water for a set period of time to precipitate solids and metal hydroxides prior to active treatment with CaO to raise the pH and precipitate metals. Another polishing step using limestone sand dumping is added at the end for additional alkalinity dosing prior to discharging into Rock Creek. These alternative costs include the following:

a. Access road for equipment and vehicle access;
b. Clearing and grubbing;
c. Stormwater runoff diversion;
d. Lined Settling Pond with sludge removal and disposal every 5 years;
e. Pebble Quicklime addition; and,
f. Limestone sand dumping.

Effectiveness:

The mainly active treatment technology in this alternative would provide significant alkalinity improvement and result in approximate load reductions to Rock Creek for net acidity and metals. The contaminant volume in surface water would be significantly reduced and the improvement in surface water quality would reduce risks to human health and the environment from exposure to surface water at the site. This alternative would achieve the RAOs and comply with ARARs to the extent practical. Short-term effectiveness should be high based on an immediate improvement to surface water; however, the long-term effectiveness will depend on the longevity of neutralizing capacity in the treatment components. Periodic O&M will be required to monitor surface water quality and to replenish or replace neutralizing materials as they become depleted or armored with metal hydroxides. Diversion and bypass of storm water should improve long-term effectiveness by minimizing water chemistry fluctuations in the AMD and minimizing potential damage from high flows during large storm events.

Implementability:

This alternative is both technically and administratively feasible. The proposed technologies are implementable using standard construction methods and equipment, and the required resources are readily available.

Costs:

The estimated costs for Alternative 3 are based on professional judgement, experience at similar sites, and estimates using the AMDTreat (version 5.0.2) software. The total estimated capital cost for Alternative 3 is $399,995. The estimated average annual O&M cost for Alternative 3 is $23,376.

7.4.10 Analysis of Poplar Spring Hollow Removal Alternatives

The alternatives developed for Poplar Spring Hollow involves AMD source reduction by limiting surface water runoff, and water treatment using passive treatment removal technologies.

7.4.10.1 Alternative 2 – 1st Settling Pond; MVFP; LLB; and 2nd settling Pond

Alternative 2 utilizes passive treatment technologies. Water from the discharge is first directed into a settling pond, which collects the water for a set period of time. This allows the suspended solids to precipitate out of the water. Solids such as iron (yellow boy or iron oxide) will settle to the bottom of the pond and collect there. This is followed by treatment in the MVFP, which then discharges into another settling pond and then a limestone leach bed prior to discharge into Rock Creek. The MVFP treatment relies on water neutralization with limestone, and biological sulfate reduction to precipitate metal sulfides, and an aeration/neutralization cell for the removal of residual aluminum and manganese. The LLB serves as an added polishing step by providing more alkalinity to buffer the acidic water.

These alternative costs include the following:

a. Line settling pond;
b. Modified vertical flow system;
    i. Equipped with automatic siphon/flush system
c. Lined settling pond; and
d. Horizontal flow – Limestone leach bed.

Effectiveness:

The use of a MVFP system coupled with an LB in this alternative would provide significant alkalinity improvement and result in approximate load reductions to Rock Creek for net acidity and metals. The contaminant volume in surface water would be significantly reduced and the improvement in surface water quality would reduce risks to human health and the environment from exposure to surface water at the site. This alternative would achieve the RAOs and comply with ARARs to the extent practical. Short-term effectiveness should be high based on an immediate improvement to surface water; however, the long-term effectiveness will depend on the longevity of neutralizing capacity in the treatment components. Periodic O&M will be required to monitor surface water quality and to replenish or replace neutralizing materials as they become depleted or armored with metal hydroxides.

The operational life of the MVFPs can be reduced by the accumulation of precipitated metals. Effective flushing of precipitated solids is essential to prevent clogging and to ensure long-term operation. Limestone leach beds can become clogged with sediment. It is therefore important that, during and after construction, erosion and sediment are carefully controlled on any slopes adjacent to the leach bed.

Implementability:

This alternative is both technically and administratively feasible. The proposed technologies are implementable using standard construction methods and equipment, and the required resources are readily available.

Costs:

The estimated costs for Alternative 2 are based on professional judgement, experience at similar sites, and estimates using the AMDTreat (version 5.0.2) software. The total estimated capital cost for Alternative 2 is $308,441. The estimated average annual O&M cost for Alternative 2 is $18,496.

7.4.10.2. Alternative 3 – 1st Settling Pond; MVFP; 2nd Settling Pond; LLB; and OLC

Alternative 3 also utilizes passive treatment technologies. Water from the discharge is first directed into a settling pond, which collects the water for a set period of time. This allows the suspended solids to precipitate out of the water. Solids such as iron (yellow boy or iron oxide) will settle to the bottom of the pond and collect there. This is followed by treatment in the MVFP, which then discharges into another settling pond and then a limestone leach bed prior to discharge into Rock Creek. The MVFP treatment relies on water neutralization with limestone, biological sulfate reduction to precipitate metal sulfides, and an aeration/neutralization cell for the removal of residual aluminum and manganese. The LLB and OLC are additional alkalinity producing system to boost the treated water prior to discharge into Rock Creek.

These alternative costs include the following:

a. Line settling pond;
b. Modified vertical flow system;
    i. Equipped with automatic siphon/flush system
c. Lined settling pond;
d. Horizontal flow – Limestone leach bed; and
e. OLC.

Effectiveness:

The use of a MVFP system coupled with the LLB and OLC in this alternative would provide significant alkalinity improvement and result in approximate load reductions to Rock Creek for net acidity and metals. The contaminant volume in surface water would be significantly reduced and the improvement in surface water quality would reduce risks to human health and the environment from exposure to surface water at the site. This alternative would achieve the RAOs and comply with ARARs to the extent practical. Short-term effectiveness should be high based on an immediate improvement to surface water; however, the long-term effectiveness will depend on the longevity of neutralizing capacity in the treatment components. Periodic O&M will be required to monitor surface water quality and to replenish or replace neutralizing materials as they become depleted or armored with metal hydroxides.

The operational life of the MVFPs can be reduced by the accumulation of precipitated metals. Effective flushing of precipitated solids is essential to prevent clogging and to ensure long-term operation. Limestone leach beds can become clogged with sediment. It is therefore important that, during and after construction, erosion and sediment are carefully controlled on any slopes adjacent to the leach bed.

Implementability:

This alternative is both technically and administratively feasible. The proposed technologies are implementable using standard construction methods and equipment, and the required resources are readily available.

Costs:

The estimated costs for Alternative 3 are based on professional judgement, experience at similar sites, and estimates using the AMDTreat (version 5.0.2) software. The total estimated capital cost for Alternative 3 is $334,781. The estimated average annual O&M cost for Alternative 3 is $18,496.

7.4.11 Analysis of Koger Fork Removal Alternatives

The alternatives developed for Koger Fork involves AMD source reduction by limiting surface water runoff, water treatment using either passive or active varieties of removal technologies, and soil capping of the depression on top of ridge.

7.4.11.1 Alternative 2 – Soil Cover (BMP); Pebble Quicklime; and OLC

Alternative 2 utilizes both active and passive treatment technologies with the active being the primary component addressing AMD at Sample location #7 and the use of BMP including grading and soil capping to prevent AMD seep generation from the refuse repository depression on top of the ridge. Sample location #7 shows the highest metal and acidity loading at this site and the active treatment is to address AMD being discharged at this location. The active treatment uses CaO to raise pH with the treated water discharged through an OLC for additional polishing. Conventional chemical treatment system will use mechanical feeders, and mixers to provide AMD treatment.

These alternative costs include the following:

a. Clearing access road for equipment and vehicle access;

b. Clearing and grubbing;
c. Regrading to divert surface runoff from the coal refuse repository;
d. An 18-inch thick soil cover installed over the coal refuse repository depression in two lightly compacted 6-inch lifts and one loose 6-inch lift. The cover would be seeded and mulched using a USDA FS-approved seed mix.
e. Pebble Quick Lime Doser; and
f. OLC.

Effectiveness:

The mainly active treatment technology in this alternative would provide significant alkalinity improvement and result in approximate load reductions to Rock Creek for net acidity and metals. The contaminant volume in surface water would be significantly reduced and the improvement in surface water quality would reduce risks to human health and the environment from exposure to surface water at the site. This alternative would achieve the RAOs and comply with ARARs to the extent practical. Short-term effectiveness should be high based on an immediate improvement to surface water after the soil cap is installed; however, the long-term effectiveness will depend on the longevity of neutralizing capacity in the active treatment system. Periodic O&M will be required to monitor surface water quality and to replenish or replace neutralizing materials as they become depleted or armored with metal hydroxides. Diversion and bypass of storm water should improve long-term effectiveness by minimizing water chemistry fluctuations in the AMD generated at location #7.

Implementability:

This alternative is both technically and administratively feasible. The proposed technologies are implementable using standard construction methods and equipment, and the required resources are readily available; however, Sample location #7 is not easy to get to, requiring extensive access road construction to make technology implementation possible.

Costs:

The estimated costs for Alternative 2 are based on professional judgement, experience at similar sites, and estimates using the AMDTreat (version 5.0.2) software. The total estimated capital cost for Alternative 2 is $225,755. The estimated average annual O&M cost for Alternative 2 is $18,496.

7.4.11.2. Alternative 3 – Soil Cover (BMP); LSD; and OLC

Alternative 3 utilizes passive treatment technologies and the use of BMP including grading and soil capping to prevent AMD seep generation from the refuse repository depression on top of the ridge and neutralization of AMD at location #7. The depression on the ridge top repository will be capped with a soil cover, and LSD and OLC treatments will be applied to address the AMD discharging from location #7. Conventional chemical treatment system will use mechanical feeders, and mixers to provide AMD treatment.

These alternative costs include the following:

a. Clearing access road for equipment and vehicle access;
b. Clearing and grubbing;

c. Regrading to divert surface runoff from the coal refuse repository;
d. An 18-inch thick soil cover installed over the coal refuse repository depression in two lightly compacted 6-inch lifts and one loose 6-inch lift. The cover would be seeded and mulched using a USDA FS-approved seed mix;
e. LSD near and downstream from location #7; and
f. OLC prior to discharge into Rock Creek.

Effectiveness:

The primarily passive treatment technology and BMPs used in this alternative would provide some alkalinity improvements and result in approximate load reductions to Rock Creek for net acidity and metals. The contaminant volume in surface water would be reduced and some improvement in surface water quality would reduce risks to human health and the environment from exposure to surface water at the site. This alternative would achieve the RAOs and comply with ARARs to the extent practical. Short-term effectiveness should be high based on an immediate improvement to surface water after the soil cap is installed; however, the long-term effectiveness will depend on the longevity of neutralizing capacity in the LSD and OLC treatments. Periodic O&M will be required to monitor surface water quality and to replenish or replace neutralizing materials as they become depleted or armored with metal hydroxides. Diversion and bypass of storm water should improve long-term effectiveness by minimizing water chemistry fluctuations in the AMD generated at location #7.

Implementability:

This alternative is both technically and administratively feasible. The proposed technologies are implementable using standard construction methods and equipment, and the required resources are readily available; however, location #7 is not easy to get to, requiring extensive access road construction to make technology implementation possible.

Costs:

The estimated costs for Alternative 3 are based on professional judgement, experience at similar sites, and estimates using the AMDTreat (version 5.0.2) software. The total estimated capital cost for Alternative 3 is $175,034. The estimated average annual O&M cost for Alternative 3 is $13,616.

7.4.12 Analysis of Water Tank Hollow Removal Alternatives

The alternatives developed for Water Tank involves AMD source reduction by limiting surface water infiltration through BMP, and seep water treatment using passive removal technologies.

7.4.12.1 Alternative 2 – Soil cover (BMP); and Permeable Reactive Barrier

Alternative 2 utilizes a passive treatment technology along with BMPs including grading and soil capping to control and treat AMD seep from the refuse pile before it discharges into Rock Creek. Alternative 2 uses a PRB consisting of a reactive mixture of chitorem® (which will contribute dissolved organic carbon), limestone sand, and granular aggregate to promote microbially-mediated sulfate reduction, generation of hydrogen sulfide, and the precipitation of metal sulfide minerals. A limestone buttress will be constructed to retain the refuse pile and control discharge of seepage across the refuse pile prior to the treated water's discharge into Rock Creek.

These alternative costs include the following:

1. Access road construction along the banks of Rock Creek to supply material and land access for removal action implementation.
2. Construction of Limestone buttress and slope stabilizer parallel to the banks of Rock Creek;
3. Approximately 600 feet PRB; 2 feet thick;
4. 4-6 years before reactive media replacement;
    a. Bio-wall material: Chitorem®, mulch, and limestone aggregates
5. Emplacement method
    a. Slurry delivery following construction of buttress; or
    b. Direct injection using multiple geoprobe grids behind the buttress.
6. Injection wells installed along barrier for further chitorem® injection when needed.
7. Regrading and placement of an 18-inch thick soil cover over the coal refuse pile in two lightly compacted 6-inch lifts and one loose 6-inch lift. The cover would be seeded and mulched using a USDA FS-approved seed mix to prevent surface water infiltration.

Effectiveness:

The PRB will provide passive interception and in-situ treatment of AMD seepage that will remove metals and decrease the acid-generating potential of the refuse pile. The primarily passive treatment technology and BMPs used in this alternative will provide significant alkalinity improvements and result in approximate load reductions to Rock Creek for net acidity and metals. The contaminant volume in surface water will be reduced and some improvement in surface water quality would reduce risks to human health and the environment from exposure to surface water at the site. This alternative would achieve the RAOs and comply with ARARs to the extent practical. Short-term effectiveness should be high based on an immediate improvement to Rock Creek after the soil cap and PRB are installed; however, the long-term effectiveness will depend on the longevity of the limestone and carbon substrate in promoting microbially mediated sulfate reduction. Periodic O&M will be required to monitor surface water quality and to replenish the Chitorem® as they become depleted.

Implementability:

This alternative is both technically and administratively feasible. The proposed technologies are implementable using standard construction methods and equipment, and the required resources are readily available. PRB technology has evolved over the past decade from the conceptual stage to broad application at mine sites and industrial sites. Several installations have demonstrated excellent treatment over several years, and PRB expected lifetimes now range from a decade to several decades.

Costs:

The estimated costs for Alternative 2 are based on professional judgement, experience at similar sites, and estimates using the AMDTreat (version 5.0.2) software. The total estimated capital cost for Alternative 2 is $348,408. The estimated average annual O&M cost for Alternative 2 is $13,616.

7.4.12.2. Alternative 3 – Soil Cover (BMP); and Limestone Sand/Aggregate Wall

Alternative 3 utilizes passive treatment technology and the use of BMPs including grading and soil capping to prevent surface water infiltration into the refuse pile and neutralization of AMD with limestone sand along the entire toe of the refuse pile. A limestone buttress will be constructed to retain the refuse pile and control discharge of seepage across the refuse pile prior to the treated water's discharge into Rock Creek. The soil cover will end where the limestone sand zone starts and together with the limestone buttress, will serve as alkalinity recharging zone (via clean surface water infiltration) to neutralize seeps located at the bottom of the pile and next to the buttress. The design is intended to intercept and treat the AMD seep primarily by neutralization. System would include piping for periodic flushing of precipitates at the bottom and prevent clogging.

These alternative costs include the following:

a. Access road construction along the banks of Rock Creek to supply material and land access for removal action implementation.
b. Construction of Limestone buttress and slope stabilizer parallel to the banks of Rock Creek;
c. Approximately 600 feet of limestone sand/aggregate alkalinity generating zone
d. Piping to periodically flush out precipitates and prevent armoring
e. Regrading and placement of an 18-inch thick soil cover over the coal refuse pile in two lightly compacted 6-inch lifts and one loose 6-inch lift. The cover would be seeded and mulched using a USDA FS-approved seed mix to prevent surface water infiltration.

Effectiveness:

The primarily passive treatment technology and BMPs used in this alternative would provide some alkalinity improvements and result in approximate load reductions to Rock Creek for net acidity and metals. The contaminant volume in Rock Creek would be reduced and some improvement in surface water quality would reduce risks to human health and the environment from exposure to surface water at the site. This alternative may achieve the RAOs and comply with ARARs to the extent practical. Short-term effectiveness should be high based on an immediate improvement to Rock Creek after the soil cap and limestone alkalinity generating zone are installed; however, the long-term effectiveness will depend on the longevity of neutralizing capacity in the alkalinity generating zone. Periodic O&M will be required to monitor surface water quality and to replenish or replace neutralizing materials as they become depleted or armored with metal hydroxides. Effective flushing of precipitated solids is essential to prevent clogging and to ensure long-term operation.

Implementability:

This alternative is both technically and administratively feasible. The proposed technologies are implementable using standard construction methods and equipment, and the required resources are readily available.

Costs:

The estimated costs for Alternative 3 are based on professional judgement, experience at similar sites, and estimates using the AMDTreat (version 5.0.2) software. The total estimated capital cost for Alternative 3 is $211,908. The estimated average annual O&M cost for Alternative 3 is $13,616.

7.4.13 Analysis of Grassy Fork Removal Alternatives

The alternative developed for Grassy Fork involves AMD source reduction by using limestone sand dumping into the tributary to neutralize the acidic water generated by the coal refuse pile located along the course of the tributary from the headwaters down to its confluence with Rock Creek.

7.4.13.1 Alternative 2 –Limestone Sand Dumping

Alternative 2 utilizes passive treatment technology to treat the AMD. It requires that sand-sized limestone be dumped directly into the AMD stream. Coating of limestone particles with Fe oxides can occur, but the agitation and scouring of limestone by the streamflow keep fresh surfaces available for reaction. It is predicted that treating the tributary with limestone sand will be necessary in order to maintain water quality. Due to the additional costs involved with the road construction necessary to create treatment structure(s) and the relatively low metal and acidity loading, LSD is the only economically feasible treatment alternative for this site.

These alternative costs include the following:

a. Existing access for all-terrain-vehicle to transport limestone sand;
b. Construction of limestone sand dumping stations along the tributary for easy dumping; and,
c. Delivery of limestone sand, as needed.

Effectiveness:

The primarily passive treatment technology used in this alternative would provide some alkalinity improvements and result in approximate load reductions to Rock Creek for net acidity and metals. The contaminant volume in Rock Creek would be reduced and some improvement in surface water quality would reduce risks to human health and the environment from exposure to surface water at the site. This alternative may achieve the RAOs and comply with ARARs to the extent practical. Short-term effectiveness should be high based on an immediate improvement to Rock Creek after the limestone sand dumping starts generating additional alkalinity to buffer the acidic water; however, the long-term effectiveness will depend on the longevity of neutralizing capacity of the limestone sand. Periodic O&M will be required to monitor surface water quality and to replenish or replace neutralizing materials as they become depleted or armored with metal hydroxides.

Implementability:

This alternative is both technically and administratively feasible. The proposed technology is implementable as long as the trail along Grassy Fork can be used to supply limestone sand to the various dumping stations that would need to be constructed.

Costs:

The estimated costs for Alternative 2 are based on professional judgement, experience at similar sites, and estimates using the AMDTreat (version 5.0.2) software. The total estimated capital cost for Alternative 2 is $94,185. The estimated average annual O&M cost for Alternative 2 is $13,616.

7.4.13.2. Alternative 3 – Pebble Quicklime; and LSD

Alternative 3 uses mainly an active treatment technology with a limestone-based treatment step for polishing. AMD is first actively treated with CaO to raise the pH and precipitate metals. Another polishing step using limestone sand dumping is added at the end for additional alkalinity dosing prior to the water's discharge into Rock Creek. These alternative costs include the following:

a. Access road for equipment and vehicle access;
b. Clearing and grubbing;
c. Pebble Quicklime addition; and,
d. Limestone sand dumping.

Effectiveness:

The mainly active treatment technology in this alternative would provide significant alkalinity improvement and result in approximate load reductions to Rock Creek for net acidity and metals. The contaminant volume in surface water would be significantly reduced and the improvement in surface water quality would reduce risks to human health and the environment from exposure to surface water at the site. This alternative would achieve the RAOs and comply with ARARs to the extent practical. Short-term effectiveness should be high based on an immediate improvement to surface water; however, the long-term effectiveness will depend on the longevity of neutralizing capacity in the treatment components. Periodic O&M will be required to monitor surface water quality and to replenish or replace neutralizing materials as they become depleted or armored with metal hydroxides.

Implementability:

This alternative is both technically and administratively feasible. The proposed technologies are implementable using standard construction methods and equipment, and the required resources are readily available.

Costs:

The estimated costs for Alternative 3 are based on professional judgement, experience at similar sites, and estimates using the AMDTreat (version 5.0.2) software. The total estimated capital cost for Alternative 3 is $215,645. The estimated average annual O&M cost for Alternative 3 is $13,616.

8. COMPARATIVE ANALYSIS OF REMOVAL ACTION ALTERNATIVES

The removal action alternatives were compared based on the following criteria:

- **Effectiveness**
  - Protective of human health and the environment
  - Complies with ARARs/TBCs
  - Achieves removal action objectives
- **Implementability**
  - Technical Feasibility
  - Administrative Feasibility
  - Availability of Resources
- **Cost**

The comparative analysis of removal action alternatives is summarized in **Table 23**. A brief overview of the comparison by site is presented below. The comparison below gives a visual qualitative summary of whether each alternative rates "High," "Medium," or "Low" for each of the evaluation factors. The purpose of the comparative analysis is to identify the advantages and disadvantages of each alternative relative to one another so that key tradeoffs that would affect the remedy selection can be identified. In this case of an Area with multiple sites, such a comparison is, of necessity, site-specific. Alternative 1, the No Action Alternative, applies to each site analyzed and is the least expensive and easiest to implement; however, it is the least effective and does not comply with ARARs or provide protection to human health or the environment.

8.1. Cabin Branch

8.1.1 Alternative 2: 1st Settling pond; MVFP; 2nd Settling pond; and Pebble Quicklime dosing.

Compliance with Removal Action Goals and Objectives:	High
Overall Protectiveness of Public Health, Safety and Welfare:	High
Environmental Protectiveness:	High
Compliance with ARARs:	High
Reduction of Toxicity, Mobility and Volume:	High
Short-Term Effectiveness:	High
Implementability:	High
Capital Cost:	$356,124
Annual Cost:	$18,496

8.1.2 Alternative 3: 1st Settling pond; MVFP; and 2nd Settling pond.

Compliance with Removal Action Goals and Objectives:	High
Overall Protectiveness of Public Health, Safety and Welfare:	High
Environmental Protectiveness:	High
Compliance with ARARs:	High

Reduction of Toxicity, Mobility and Volume:	High
Short-Term Effectiveness:	High
Implementability:	High
Capital Cost:	$287,814
Annual Cost:	$23,376

Both Alternatives 2 and 3 are easy to implement and technically and administratively feasible; however, Alternative 2 should provide significantly higher acidity removal than Alternative 3 due to the use of an active treatment technology, which is expected to remove more of the metals under proper design conditions. The long-term effectiveness for both alternatives is speculative and will need to be evaluated through periodic surface water quality monitoring. In addition, long-term maintenance will be required to ensure continued effectiveness and permanence.

8.2. Big Momma

8.2.1 Alternative 2: ALD; MVFP; and Settling pond.

Compliance with Removal Action Goals and Objectives:	High
Overall Protectiveness of Public Health, Safety and Welfare:	High
Environmental Protectiveness:	High
Compliance with ARARs:	High
Reduction of Toxicity, Mobility and Volume:	High
Short-Term Effectiveness:	Medium
Implementability:	High
Capital Cost:	$386,092
Annual Cost:	$18,496

8.2.2 Alternative 3: 1st Settling pond; MVFP; and 2nd Settling pond.

Compliance with Removal Action Goals and Objectives:	High
Overall Protectiveness of Public Health, Safety and Welfare:	High
Environmental Protectiveness:	High
Compliance with ARARs:	High
Reduction of Toxicity, Mobility and Volume:	High
Short-Term Effectiveness:	High
Implementability:	High
Capital Cost:	$392,217
Annual Cost:	$23,376

8.2.3 Alternative 4: MVFP; Settling pond; Caustic Soda dosing; LSD.

Compliance with Removal Action Goals and Objectives:	High
Overall Protectiveness of Public Health, Safety and Welfare:	High
Environmental Protectiveness:	High

Compliance with ARARs:	High
Reduction of Toxicity, Mobility and Volume:	High
Short-Term Effectiveness:	High
Implementability:	High
Capital Cost:	$329,571
Annual Cost:	$18,496

All three alternatives are easy to implement and technically and administratively feasible and should provide significantly elevated acidity and metals removals. The long-term effectiveness for all alternatives is speculative and will need to be evaluated through periodic surface water quality monitoring. In addition, long-term maintenance will be required to ensure continued effectiveness and permanence; however, based on the site conditions, long-term O&M requirements, and confidence in the effectiveness of using two settling ponds, Alternative 3 appears to be preferred.

8.3. Cooperative South

8.3.1 Alternative 2: OLC; Settling pond; and LSD.

Compliance with Removal Action Goals and Objectives:	High
Overall Protectiveness of Public Health, Safety and Welfare:	High
Environmental Protectiveness:	Medium
Compliance with ARARs:	Medium
Reduction of Toxicity, Mobility and Volume:	High
Short-Term Effectiveness:	Medium
Implementability:	High
Capital Cost:	$171,414
Annual Cost:	$18,496

8.3.2 Alternative 3: LSD; Settling pond; and LSD.

Compliance with Removal Action Goals and Objectives:	High
Overall Protectiveness of Public Health, Safety and Welfare:	High
Environmental Protectiveness:	Medium
Compliance with ARARs:	Medium
Reduction of Toxicity, Mobility and Volume:	Medium
Short-Term Effectiveness:	Medium
Implementability:	High
Capital Cost:	$165,244
Annual Cost:	$18,496

Both alternatives for Cooperative South would be easy to implement and technically and administratively feasible. Alternative 2 utilizes an OLC to increase the acidity of the left tributary prior to its confluence with the right tributary, which has a lower pH and greater metal contamination. After combining, the waters of the tributaries will reach near neutral pH. Significant metals removal will occur because of the long retention time in the settling pond and LSD polishing. Alternative 3 replaces the OLC on the left tributary with LSD and increases the length of the settling pond. Due to the near-neutral pH of the left tributary, LSD instead of OLC may be sufficient to raise the pH of the combined tributaries. The use of a longer settling pond is to counter for the potentially lower pH of the influent. Both alternatives should provide for substantial metals removal; however, the additional reduction in pH associated with Alternative 2 would be preferable. In addition, if the OLC is constructed to maximize design output, the need to add sand-sized limestone along the left tributary prior to the convergence of the two tributaries will be eliminated. The long-term effectiveness of these alternatives is speculative and will need to be evaluated through periodic surface water quality monitoring. In addition, long-term maintenance will be required to ensure continued effectiveness and permanence.

8.4. Jones Branch:

8.4.1 Alternative 2: 1st Settling pond; 1st MVFP; 2nd MVFP; 2nd Settling pond; and LSD.

Compliance with Removal Action Goals and Objectives:	High
Overall Protectiveness of Public Health, Safety and Welfare:	High
Environmental Protectiveness:	High
Compliance with ARARs:	High
Reduction of Toxicity, Mobility and Volume:	High
Short-Term Effectiveness:	High
Implementability:	High
Capital Cost:	$441,220
Annual Cost:	$23,376

8.4.2 Alternative 3: ALD; Settling pond; MVFP; LSD; Pebble Quicklime dosing.

Compliance with Removal Action Goals and Objectives:	High
Overall Protectiveness of Public Health, Safety and Welfare:	High
Environmental Protectiveness:	High
Compliance with ARARs:	High
Reduction of Toxicity, Mobility and Volume:	High
Short-Term Effectiveness:	High
Capital Cost:	$375,461
Annual Cost:	$18,496

Both Alternatives 2 and 3 are easy to implement and technically and administratively feasible. Alternative 3 should provide significantly higher acidity removal than Alternative 2 due to the use of both active and passive treatment options, which will lead to significantly better metals removal under proper design conditions. The long-term effectiveness for both alternatives is speculative and will need to be evaluated through periodic surface water quality monitoring. In addition, long-term maintenance will be required to ensure continued effectiveness and permanence.

8.5. Paint Cliff/Mine 16 Complex:

8.5.1 Alternative 2: Settling pond; Pebble Quicklime dosing; and OLC.

Compliance with Removal Action Goals and Objectives:	High
Overall Protectiveness of Public Health, Safety and Welfare:	High
Environmental Protectiveness:	High
Compliance with ARARs:	High
Reduction of Toxicity, Mobility and Volume:	High
Short-Term Effectiveness:	High
Implementability:	High
Capital Cost:	$433,632
Annual Cost:	$18,496

8.5.2 Alternative 3: 1st Settling pond; 1st MVFP; 2nd MVFP; 2nd Settling pond; and OLC.

Compliance with Removal Action Goals and Objectives:	High
Overall Protectiveness of Public Health, Safety and Welfare:	High
Environmental Protectiveness:	High
Compliance with ARARs:	High
Reduction of Toxicity, Mobility and Volume:	High
Short-Term Effectiveness:	High
Implementability:	High
Capital Cost:	$555,182
Annual Cost:	$18,496

Both Alternatives 2 and 3 are easy to implement and technically and administratively feasible. Alternative 3 should provide significantly higher acidity removal than Alternative 2 due to the use of two MVFP systems, which will lead to significantly better metals removal under proper design conditions; however, if the existing system at the site is properly reconfigured and improved upon, Alternative 2 should also perform well. The long-term effectiveness for both alternatives is speculative and will need to be evaluated through periodic surface water quality monitoring. In addition, long-term maintenance will be required to ensure continued effectiveness and permanence.

8.6. Roberts Hollow:

8.6.1 Alternative 2: 1st Settling pond; 1st MVFP; 2nd MVFP; 2nd Settling pond; LSD.

Compliance with Removal Action Goals and Objectives:	High
Overall Protectiveness of Public Health, Safety and Welfare:	High
Environmental Protectiveness:	High
Compliance with ARARs:	High
Reduction of Toxicity, Mobility and Volume:	High
Short-Term Effectiveness:	High

Implementability:	High
Capital Cost:	$463,998
Annual Cost:	$23,376

8.6.2 Alternative 3: 1st Settling pond; Pebble Quicklime dosing; 2nd Settling pond; and LSD.

Compliance with Removal Action Goals and Objectives:	High
Overall Protectiveness of Public Health, Safety and Welfare:	High
Environmental Protectiveness:	High
Compliance with ARARs:	High
Reduction of Toxicity, Mobility and Volume:	High
Short-Term Effectiveness:	High
Implementability:	High
Capital Cost:	$399,995
Annual Cost:	$23,376

Both Alternatives 2 and 3 are easy to implement and technically and administratively feasible. Alternative 2 should provide significantly higher acidity removal than Alternative 3 due to the use of two MVFP systems, which will lead to significantly better metals removal under proper design conditions; however, Alternative 3 should also perform well due to the use of active removal technology as the primary treatment option. The long-term effectiveness for both alternatives is speculative and will need to be evaluated through periodic surface water quality monitoring. In addition, long-term maintenance will be required to ensure continued effectiveness and permanence.

8.7. Poplar Spring:

8.7.1 Alternative 2: 1st Settling pond; MVFP; 2nd Settling pond; LB.

Compliance with Removal Action Goals and Objectives:	High
Overall Protectiveness of Public Health, Safety and Welfare:	High
Environmental Protectiveness:	High
Compliance with ARARs:	High
Reduction of Toxicity, Mobility and Volume:	High
Short-Term Effectiveness:	High
Implementability:	High
Capital Cost:	$308,441
Annual Cost:	$18,496

8.7.2 Alternative 3: 1st Settling pond; MVFP; 2nd Settling pond; LB; and OLC.

Compliance with Removal Action Goals and Objectives:	High
Overall Protectiveness of Public Health, Safety and Welfare:	High
Environmental Protectiveness:	High
Compliance with ARARs:	High

Reduction of Toxicity, Mobility and Volume:	High
Short-Term Effectiveness:	High
Implementability:	High
Capital Cost:	$334,781
Annual Cost:	$18,496

Both Alternatives 2 and 3 are easy to implement and technically and administratively feasible. Alternative 3 should provide significantly higher acidity removal than Alternative 2 due to the addition of another polishing step with an OLC, which will lead to slightly better metals removal under proper design conditions. The long-term effectiveness for both alternatives is speculative and will need to be evaluated through periodic surface water quality monitoring. In addition, long-term maintenance will be required to ensure continued effectiveness and permanence.

8.8. Koger Fork:

8.8.1 Alternative 2: Soil Cover (BMP); Pebble Quicklime dosing; and OLC.

Compliance with Removal Action Goals and Objectives:	High
Overall Protectiveness of Public Health, Safety and Welfare:	High
Environmental Protectiveness:	High
Compliance with ARARs:	High
Reduction of Toxicity, Mobility and Volume:	High
Short-Term Effectiveness:	High
Implementability:	High
Capital Cost:	$225,755
Annual Cost:	$18,496

8.8.2 Alternative 3: Soil Cover (BMP); OLC; and LSD.

Compliance with Removal Action Goals and Objectives:	Medium
Overall Protectiveness of Public Health, Safety and Welfare:	Medium
Environmental Protectiveness:	High
Compliance with ARARs:	Medium
Reduction of Toxicity, Mobility and Volume:	Medium
Short-Term Effectiveness:	High
Implementability:	High
Capital Cost:	$175,034
Annual Cost:	$13,616

Both Alternatives 2 and 3 are easy to implement and technically and administratively feasible. Alternative 2 should provide significantly higher acidity removal than Alternative 3 because an active treatment is being proposed at Sample location #7 along with soil capping of the depressions on top of the ridge, which will lead to significantly better metals removal under proper design conditions; however, Alternative 3 focuses mainly on soil capping and limestone sand dumping at Sample location #7 which should also perform well.

The long-term effectiveness for both alternatives is speculative and will need to be evaluated through periodic surface water quality monitoring. In addition, long-term maintenance will be required to ensure continued effectiveness and permanence.

8.9. Water Tank:

8.9.1 Alternative 2: Soil Cover (BMP); and Permeable Reactive Barrier wall.

Compliance with Removal Action Goals and Objectives:	High
Overall Protectiveness of Public Health, Safety and Welfare:	High
Environmental Protectiveness:	High
Compliance with ARARs:	High
Reduction of Toxicity, Mobility and Volume:	High
Short-Term Effectiveness:	High
Implementability:	High
Capital Cost:	$348,408
Annual Cost:	$13,616

8.9.2 Alternative 3: Soil Cover (BMP); and LSD.

Compliance with Removal Action Goals and Objectives:	Medium
Overall Protectiveness of Public Health, Safety and Welfare:	High
Environmental Protectiveness:	High
Compliance with ARARs:	Medium
Reduction of Toxicity, Mobility and Volume:	Medium
Short-Term Effectiveness:	High
Implementability:	High
Capital Cost:	$211,908
Annual Cost:	$13,616

Both Alternatives 2 and 3 are easy to implement and technically and administratively feasible. In addition, both should provide significantly acidity and metals removal under proper design conditions. Alternative 2 focuses mainly on controlling surface water infiltration through the refuse pile and in-situ bioremediation via biologically-mediated reactions of AMD seeps along the toe of the refuse pile. Alternative 3 also relies on the soil cover controlling infiltration and the limestone sand and buttress acting as an alkalinity producing zone to neutralize the acidity generated at the toe of the refuse pile. The long-term effectiveness for both alternatives is speculative and will need to be evaluated through periodic surface water quality monitoring. In addition, long-term maintenance will be required to ensure continued effectiveness and permanence.

8.10. Grassy Fork

8.10.1 Alternative 2: LSD

Compliance with Removal Action Goals and Objectives:	Medium

Overall Protectiveness of Public Health, Safety and Welfare:	Medium
Environmental Protectiveness:	Medium
Compliance with ARARs:	Medium
Reduction of Toxicity, Mobility and Volume:	Medium
Short-Term Effectiveness:	High
Implementability:	High
Capital Cost:	$94,185
Annual Cost:	$13,616

8.10.2 Alternative 3: Pebble Quicklime; and LSD

Compliance with Removal Action Goals and Objectives:	High
Overall Protectiveness of Public Health, Safety and Welfare:	High
Environmental Protectiveness:	High
Compliance with ARARs:	High
Reduction of Toxicity, Mobility and Volume:	High
Short-Term Effectiveness:	High
Implementability:	High
Capital Cost:	$215,645
Annual Cost:	$13,616

Alternative 2 is easy to implement and technically and administratively feasible. It consists of limestone sand dumping and would comply with some, but not all, ARARs and provide some protection of human health and the environment. Alternative 2 provides an adequate amount of acidity removal when compared to No Action. However, large volumes of limestone sand will need to be dumped at dumping stations along Grassy Fork to encourage better metals removal. The long-term effectiveness for this alternative is speculative and will need to be evaluated through periodic surface water quality Grassy Fork. In addition, long-term maintenance will be required to ensure continued effectiveness and permanence. In comparison, Alternative 3 should provide significantly higher acidity removal than Alternative 2 due to the higher neutralization efficiency (approximately 90%) of quicklime, which will lead to significantly better metals removal under proper design conditions. Despite the greater efficiency of this alternative, the high access costs and long-term system maintenance requirements associated with Alternative 3 outweigh the potential benefits of this alternative.

9. RECOMMENDED REMOVAL ACTION ALTERNATIVES

The recommended removal action alternative was selected based on the analysis summarized above and in **Table 23**. Key options of the recommended removal action alternative are discussed below. Details are provided below along with removal action schematics associated with each site. The recommended alternatives for majority of the sites are a combination of limestone-based passive treatment technologies and in a few instances active treatment using either pebble quicklime or caustic soda. The recommended alternatives consist of the following:

Cabin Branch

- Alternative 3: 1st settling pond; MVFP; and 2nd settling pond (see **Figure 28-1**).
  Capital Cost: $287,814
  Annual Cost: $23,376

Big Momma

- Alternative 3: 1st settling pond; MVFP; and 2nd settling pond (see **Figure 28-2**).
- Capital Cost: $392,271
  Annual Cost: $23,376

Cooperative South

- Alternative 2: OLC; Settling pond; and LSD (see **Figure 28-3**).
- Capital Cost: $171,414
  Annual Cost: $18,496

Jones Branch:

- Alternative 2: 1st settling pond; 1st MVFP; 2nd MVFP; 2nd settling pond; and LSD (see **Figure 28-4**).
- Capital Cost: $441,220
  Annual Cost: $23,376

Paint Cliff/Mine 16 Complex:

- Alternative 3: 1st settling pond; 1st MVFP; 2nd MVFP; 2nd settling pond; and OLC (see **Figure 28-5**).
- Capital Cost: $555,182
  Annual Cost: $18,496

Roberts Hollow:

- Alternative 2: 1st settling pond; 1st MVFP; 2nd MVFP; 2nd settling pond; LSD (see **Figure 28-6**).
- Capital Cost: $463,998
  Annual Cost: $23,376

Poplar Spring:

- Alternative 3: 1st settling pond; MVFP; 2nd settling pond; LB; and OLC (see **Figure 28-7**).
- Capital Cost: $334,781
  Annual Cost: $18,496

Koger Fork:

- Alternative 3: Soil Capping via BMP; OLC; and LSD (see **Figure 28-8**).
- Capital Cost: $175,034
  Annual Cost: $13,616

Water Tank:

- Alternative 2: Soil capping via BMP; and PRB wall (see **Figure 28-9**).
- Capital Cost: $348,408
  Annual Cost: $13,616

Grassy Fork:

- Alternative 2: LSD (see **Figure 28-10**).
- Capital Cost: $94,185
  Annual Cost: $13,616

The total estimated removal action cost for the Rock Creek abandoned mine sites is $3,454,093 and the estimated average annual O&M cost is $18,984 per site including the periodic replacement of lime-based components. Long-term monitoring of water quality in White Oak and Rock Creek that will be done as part of the overall project plan will allow the USDA FS to regularly evaluate whether these alternatives continue to be appropriate for the watershed.

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Appendix A

Summary of Historical (2002 – 2010) Analytical Data – Coal Mine Features, and Preliminary Assessment /Site Inspection and Stream Samples

APPENDIX B

Site Visit and EE/CA Investigation Photographs and Notes

Cabin Branch and Unnamed Branch

Field Observation Notes on 10/28/2013:

1. Observed two refuse piles A and B.
2. In the upper reaches of the creek, past refuse pile A, a road over a culvert connected to the previously mined hill.
3. An upper limestone sand dumping station was located along the northwest portion of refuse pile A. A pile of limestone sand was observed within the limits of this refuse pile.
4. Three portals were observed near refuse pile B. The first portal was open and about 75 feet away from it westward was the second portal, which was partially covered. The third portal was completely covered and a major AMD seep was seen discharging from this location (1-2 gallons per minute [gpm]).
5. A pool of AMD was observed some distance away from refuse pile B and closer to the intersection with the main ditch draining Cabin Branch.
6. The portals were used to move coal, another for the fan house for ventilation, and the third to move equipment and utilities.
7. A very steep slope exists between the pool and the main ditch.
8. Ditches were lined with limestone starting from the upper reaches to the confluence with White Oak Creek. The unnamed tributary connecting refuse pile B to the main Cabin Branch ditch was also lined.
9. Ditches were lined twice with this limestone.
10. Very steep topography. Impossible to implement a passive treatment system in this area. Active treatment appears to be the only option. Doser can be used to deliver alkalinity reagents to seep in the upper reaches of the site. Fly ash slurry can also be considered to boost the alkalinity via injection from top of knoll into mine.
11. The problem with dosing at Cabin is how long will solid and/or liquid dosing last once it begins. If just looking at reducing the AMD impact at Cabin Branch, dosing can be implemented and followed with a series of settling pond constructed on the side of the hill – Hillside Bench Ponds.
12. Estimated volume of refuse not much at this site.
13. USDA FS plans to close the open portals.
14. No mining was performed upgradient of Cabin Branch. The major contribution of AMD is from seep in the refuse B pile.
15. Different flow rates where noted between the seeps in the upper reaches of the ditch and at the mouth with White Oak Creek.

Field Observation Notes on 10/30/2013: Unnamed Branch Mine

1. Seven portals total were observed. Five were located immediately north of refuse pile C and on the eastern side of the ditch. The fifth portal, located closest to the ditch, was collapsed and had AMD discharges. A very small pond (approximately 4 x 4 ft.) was observed in front of the fifth portal.
2. The sixth and seventh portals are located on the western side of the ditch.
3. Ditches are all lined with limestone rocks.
4. Coal refuse at one time covered the entire ditch but current conditions show the ditch has since cut through the refuse and now has an open channel between.
5. Spontaneous fire is typical at this site involving the heating of coal, shale, and sandstone and creating what is commonly known as “red dogs”.

Cabin Branch and Unnamed Branch Investigation Photographs

Big Momma Mine

Field Observation Notes on 10/29/2013:

1. One seep location and approximately 50 x 30 ft. pond immediately downgradient of portal.
2. USFS does not believe there was mining at the pond location
3. Seep discharges at 55-60 gpm.
4. Very steep topography from pond down to hwy.
5. There is an old road by the side of the hill that can be used to transport material to the pond location.
6. No refuse pile was observed.
7. Open limestone channel from adit and portal pond to base of hill.
8. It is believed that the limestone is influencing the water quality. pH of 6.72 was reported and believed to be because of the buffering by the limestone.
9. Going downhill from Big Momma, there exists a settling basin to the right and next to Hwy 1363. This basin can be expanded to create room for one or a combination of passive systems.

Big Momma Mine Investigation Photographs

Cooperative South Mine

Field Observation Notes on 10/29/2013:

1. Walked up from Hwy to confluence of right (RT) and left (LT) branches of AMD seeps.
2. Observed possibly Aluminum hydroxide precipitate in the mixing area where the RT and LT branches of the seeps meet.
3. Historical pH of the RT seep was reported at 4.5; however, measurements taken with a pH paper showed pH to be around 7.
4. URS hiked up along the RT seep towards the ridge of refuse piles; one open portal; and one collapsed portal with sinking seeps. The refuse piles had vegetative cover with mature trees growing on them. Based on the condition of the refuse pile, the question was asked whether it was worth disturbing the refuse pile for fear of generating additional AMD during the process.
5. Ground surface subsidence was observed near portal opening and two circular ones near the top of the ridge.
6. Hiked across over to the headwaters of the LT seep. Significant flow and precipitation was observed along the LT branch up to the fallen sandstone block within the path of the seep.
7. pH along the LT branch ranged from 9.5 to 10.5, measured using a pH paper.
8. Pond located along the LT branch is believed to be man-made for the community that lived there during the mining activities.
9. The two branches bring in low and high pH waters from their respective sources. The two streams can be combined to neutralize the AMD.
10. The confluence with White Oak Creek was inspected and the discharge did not have the typical AMD color.
11. A spring box was observed near the confluence of the two branches. The pH of the water in the box was measured with a pH paper and it was alkaline.

Cooperative South Investigation Photographs

Jones Branch Mine

Field Observation Notes on 10/29/2013:

1. Three refuse piles A (2.5 acres), B (2.2 acres), and C (10 acres) are present at the site.
2. An adit and a portal pond/wetland with cattails are located west of refuse pile A. The seep coming out of the adit is not much (<1 gpm).
3. A whitish seep was observed between refuse piles A and C.
4. Entire ditch network was lined with limestone rocks.
5. Walked the entire ditch between refuse piles B and C to assess whether seeps will be seen at the toe of the refuse piles.
6. Another adit is located to the south east of refuse pile B with a limestone channel draining the AMD from this location into the main drainage ditch. Flow was conveyed under the access road into the main drainage ditch via a concrete pipe.
7. Two unnamed tributaries located to the east and south of refuse pile C also drain into the main drainage ditch. The eastern tributary was sampled in 2009 and appeared not to have been impacted by AMD.
8. The southern tributary will be sampled in 2013/2014 to determine presence or absence of AMD. Discharge from this tributary does not indicate impact.
9. AMD treatment system constructed - circulatory flow system of Successive Alkalinity Producing System (SAPS). Initially, things worked well. pH rose from 2.5 to 7.5; however, six months to one year into the implementation, things started tapering and by end of the second year, system stopped working.
10. We started getting lamina flow on top, and therefore, not much treatment.
11. All the sludge was dredged buried.
12. Second phase – put in 6” PVC pipe through the wall.

Jones Branch Mine Investigation Photographs

Upper Rock Creek Fidelity North Mine

Field Observation Notes on 10/31/2013:

1. Seep observes along Kentucky Highway 1363; however, wet terrain exists immediately north of the ditches and some distance inland in the direction of the collapsed adit.
2. A thick precipitation of yellow boy was observed near the adit. The AMD seep coming out of adit was continuous at <2 gpm.
3. The AMD discharge did not flow into Rock Creek. URS walked the banks of the Rock Creek and there was no evidence of seepage.

Upper Rock Creek Fidelity North Mine Investigation Photographs

Paint Cliff Mine

Field Observation Notes on 10/30/2013:

1. 30 ft. of coal removed from the site, where the current remedial system is constructed.
2. Mine adit and AMD is located to the north of the remedial system in the area of the former underground mining.
3. Two sources for the AMD – one piped directly from the underground mine pool and another seep from the mine portal located near the piped AMD. There is also a bypass drainage pipe connected to the piped supply line to handle high flows that exceed pipe capacity. The bypass drainage pipe discharges into the open channel limestone ditches which receives the AMD seep from the portal.
4. Piped AMD is discharged directly into rectangular limestone pond system.
5. The AMD seep from portal discharging into the limestone ditches ultimately discharges into three existing wetland treatment systems – first into one and sequentially into the other two.
6. It appears the wetlands are not lined and there exists the potential for AMD to migrate downward into the groundwater below.
7. The three wetland systems appeared to be under-sized for the intended purpose of treating the AMD. Iron oxidation stains were observed along the sides of the wetlands and the open channel limestone ditches that connected the treated water with the settling ponds across KY Highway 1363.
8. Seeps were also observed in ditches along the highway.
9. The settling ponds appeared to contain lots of sludge and needed to be dredged.
10. Final discharge into Rock Creek appeared to contain AMD. Seeps were also observed along the creek bank closest to the settling ponds.

Paint Cliff Mine Investigation Photographs

Roberts Hollow Mine

Field Observation Notes on 10/30/2013:

1. Observed entire creek (from upgradient of refuse A to confluence with White Oak Creek) was lined with #2 and #4 limestone – open limestone channel.
2. Water quality appears normal in the ditch above refuse A.
3. Collapsed adit located northeast of refuse pile "B". One of the worst contributors of AMD; although the refuse pile is also contributing.
4. There is an unnamed tributary located west and southwest of the collapsed adit located above refuse B.
5. Immediately south of refuse B, very low pH water was measured, which was believed to be seeping from the refuse pile, in addition to contributions from upgradient source (refuse A). A whitish pool of AMD was also observed within the limestone channel located south of the refuse B pile.
6. A water quality sample was proposed to be collected immediately upstream from the pool to assess the quality of the seep coming from the toe of the refuse.
7. Very low pH was measured using a pH paper next to the refuse B pile; however, the pH increased towards the middle of the creek causing a precipitate to form on the creek bed.
8. Three closed mine openings are located between refuse B and refuse C. Where the mine is close to outcrop, the AMD is feeding the refuse piles.
9. Southwest of refuse pile C, groundwater discharges into the Roberts Hollow Creek and mixes with seep originating from the west side of the refuse pile.
10. Seeps were confirmed along the creek banks and slope located south of the refuse pile C, especially south and southwest of the gravel road and the creek. This observation was confirmed by the presence of cattails and needle sage grass.

Roberts Hollow Mine Investigation Photographs

Poplar Spring Hollow Mine

Field Observation Notes on 10/30/2013 and 11/20/2013:

1. Open limestone ditch around the refuse pile and also down the creek to confluence with Rock Creek.
2. Seep was observed in the upper mid-section of the refuse pile area. Black spoils were observed near the seep and <1 gpm of AMD seeping from this opening.
3. AMD seep from the adit pool located on the northern/northeast corner of the refuse pile is the only real problem at this site.
4. Remnant railroad spur and bridge structure sections were observed near the bottom of the site.
5. The limestone lined ditches along the north- south tributary and east-west oriented ditch along the former railroad spur do not appear to have any significant surface water impacts.
6. The focus will be on treating the AMD from the adit pool.

Poplar Spring Hollow Mine Investigation Photographs

Koger Fork Mine

USDA Provided Information during Field Visit on 11/19/2013:

1. An estimated 32,000 to 40,000 cubic yards of acid-toxic forming coal waste from the Water Tank railroad coal refuse waste dump, and placed it in a ridge top repository, at the headwaters of Koger Fork.
2. An approximately 12-acre area was cleared and grubbed of woody vegetation and topsoil stockpiled for cover of the coal refuse. Of this 12-acre clearing, a projected 2 acres were utilized for stockpiling of clearing and grubbing debris, topsoil and construction of the haul road. A compacted clay cap was not installed; nor was a lime barrier utilized.
3. A compacted clay cap was not installed; nor was a lime barrier utilized. The deeper coal refuse is located near the ridge top, tapering/thinning in depth down gradient to the perimeter of the clearing limits, generating a projected average depth of coal waste of 2 to 2.5 feet; approximately 32,000 to 40,00 cubic yards.
4. About two years after the coal refuse was covered with soil (saved at the beginning of the project), and revegetated, a number of problems began to appear. First, acid-toxic flows from the repository started killing all vegetative ground cover and standing trees in a number of first order drainages along the perimeter of the project. Secondly, a number of "hot spots" begin to appear randomly on the surface of the repository. These 'hot spots' were small areas where capillary action brought low pH water from within the coal waste to the surface, killing the grasses and legumes established for erosion control when the site was reclaimed. To address these problems limestone channel liner was placed at the heads of the affected ephemeral drainages to prevent further head cutting of gullies into the coal refuse, and reduce downslope erosion.
5. In addition, for a number of years the whole area received heavy applications of agricultural lime (3 to 6 tons/acre/year) to boost alkalinity of groundwater, and top-dressed with fertilizer to improve growth of vegetative cover.
6. A number of test pits created randomly on this site, often found a seasonally high water table present in the coal refuse. I believe based on this finding, the site was graded to not drain evenly along the perimeter, but excavated so that the floor of the pit lies below the surface elevation of the surrounding area, yet day lighting at the elevation of the respective ephemeral drainage channels. This pit essentially traps precipitation/snow melt and surface runoff, periodically saturating the coal refuse. This rise and fall of groundwater tends to periodically flush pollutants/contaminants created with oxidation of pyrites entrained in the refuse downslope, adversely impacting ephemeral drainages and water quality downstream.
7. Coal refuse repository located on top of ridge and appears to be generating AMD, which seeps to the eastern and western tributaries of Koger Fork. The ridge top has a saddle feature and a pond. A large section of the ridge top appears to receive rainwater that remains stored in these depressions and continues to infiltrate into the refuse pile, causing the generation of the AMD down below.

Koger Fork Mine Investigation Photographs

Water Tank Hollow Mine

Field Observation Notes on 10/20/2013 and 10/31/2013:

1. Inspected sample location WTH-1 from the Hwy and the water does not appear to be impacted. Steep slope down to the sampling point from the Hwy.
2. Water quality along WTH does not appear to be impaired. The impact to Rock Creek near WTH is associated with the coal refuse pile located along the highway. Exposed surfaces of the refuse were visible during the site visit. AMD seeps were also observed along the mid-section and toe of the refuse pile; and banks with Rock Creek. The limestone diversion ditches installed at approximately mid-section of the refuse pile and perpendicular to surface water runoff from the highway do not appear to be functioning as intended. The current condition of the ditches facilitates infiltration of surface runoff into the refuse pile, thereby increasing the generation of seeps at the toe and eventual discharge into Rock Creek.
3. The volumes of flow at the seeps observed along the mid-section of the refuse pile were not enough to recommend collecting water samples from these locations. However, pore water investigation along the toe of the refuse pile is recommended to evaluate the quality of the water discharging into the creek.
4. The reclaimed refuse was transported to Roberts Hollow and placed in a repository. The reclamation was not complete because AMD is still seeping from the toe of the refuse into Rock Creek.

Water Tank Hollow Mine Investigation Photographs

Grassy Fork Mine

Field Observation Notes on 11/19/2013:

1. pH paper readings taken along Grassy Fork did not show the possibility of impaired surface water quality. Readings were mostly around 7.0 to 7.5, except at the fanhouse where a pH of 6.5 was measured.
2. Only concern at the moment is the fanhouse from a safety standpoint.
3. Reclamation is a possibility to consider since the value of coal at this location appears to be high. If taking this route, the stream would need to be rebuilt.

Grassy Fork Mine Investigation Photographs

APPENDIX C

EE/CA Site Investigation Chain-of-Custody and Laboratory Analytical Data Package

APPENDIX D

Applicable or Relevant and Appropriate Requirements (ARARs)

APPENDIX E

Removal Action Detailed Cost Sheets and Engineering Cost Estimates